S. S. "Paris"

THE PROGRESS

-- OF --

MARINE - ENGINEERING,

From the time of Watt until the present day.

WITH SIXTY-SEVEN ILLUSTRATIONS.

By T. MAIN, M. E.

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and expanded in two, three, and four cylinders in succession, the cylinders have been fitted with steam jackets formed by hard cast iron liners, (suitable to stand the wear of the piston packing rings,) which are secured and made steam tight by means of a flange on the bottom end, and by a copper strip caulked into a tapering recess at the top end, the jackets are kept free from water and air. This provision is very necessary in order to prevent the cooling of the steam by expansion below the temperature due to its pressure, and the reduction of the mean pressure in the cylinders. The surface condenser has been improved so that fresh water may be supplied to marine boilers, and evaporators have been introduced for replenishing the waste of fresh water.

Cylindrical steel boilers with corrugated furnaces have been introduced making it possible to carry pressures up to 200 lbs. And now water-tube boilers are coming into use, in which pressures up to 400 lbs. may be safely carried.

High speed balanced engines constructed of best material, with good workmanship, have been introduced making it possible to obtain the maximum of work, with the minimum weight of engines; and balanced or compensating cranks, with the pistons connected to them moving in opposite directions, greatly reduce the friction on the main bearings. Recent experiments have shown that the friction on these bearings amounts to from one-third to one-half of all the friction resistance of the engines.

Feed water heaters have been brought into use,

which abstract and utilize the heat from the exhaust steam in order to heat the feed water. Artificial or forced draught has been introduced on the closed fire-room system for the purpose of increasing the steaming power of the boilers, and to generate sufficient steam from small boilers. This system has been characterized as "one for obtaining an increase of power regardless of expense." The effect on the boilers, whenever a furnace door is opened, of the rush of a column of cold air into the furnace is most injurious to the furnace and tube plates.

The closed furnace hot-blast system while equally effective is much more economical on account of utilizing the heat and reducing the temperature of the waste furnace gases, in order to heat the blast which supports combustion. The furnace is under complete control, and there is no injury resulting from cold air entering the furnace.

Methods of feeding aud shaking grates are coming into use, so that there may be a continuous coking and heating of the coal, preventing smoke, and that the grates may be kept free from clinkers and ashes.

These improvements have been traced and examples given in the British and European, as well as in the United States Mercantile and Naval Marine, where progress was evinced.

Watt's patents have been noticed, as well as those of Woolf, Earle, Napier's, Seguine, G. Stephenson, Fulton, R. L. Stevens, Adam Hall, Ernest Wolff, Hinrick Zander, McNaught, Bodmer, Meyer, J. Bourne, C.

W. Williams, Elder, Cowper, Kirk, Brock, Hall, Spencer, Sewell, Allen, Lighthall, Volz, Wheeler, Sickels, Dickerson, J. B. Neilson, Siemens, F. B. Blanchard, W. Gorman, Howden, R. Wylie, T. Main, Belleville, Roberts, Almy, &c.

In the first six chapters the early experiments in steam navigation, the adoption of improvements, and the opposition to them also, have been noticed. In the seventh chapter or conclusion the various economical improvements, and the principles which control them have been considered. The direction in which further progress may be obtained has been reviewed, and the history of the management of Cornish engines cited as an example to the owners of steamships. In tracing out these improvements I have in addition to my own notes, consulted Lardner, Tredgold, Bourne, Mechanics Magazine, Artizan, Reed, White, Rankine, Thurston, Preble, Prideaux, Grier, Weissenborn, C. Wye Williams, D. K. Clark, Siemens, Mallet, Haswell, Nystrom, King, Tomlinson, Bartol, Kirkaldy, Johnson, Isherwood and Engineering.

The author was prompted to prepare this work on account of the opposition and misrepresentation which he met with in working his patents, and he most respectfully submits it for the consideration of all who are interested in the progress and prosperity of marine engineering. He tenders most grateful thanks to those who were instrumental in introducing his patents.

THOMAS MAIN.

NEW YORK, 19TH MAY, 1893.

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THE PROGRESS OF MARINE ENGINEERING FROM THE TIME OF WATT UNTIL THE PRESENT DAY.

CHAPTER I.

FROM the days of Hero of Alexandria, about 120 years B. C., who constructed a rotary steam engine, until the time of Watt, A. D., 1769, many experiments had been tried by Somerset, Papin, Savery, Newcomen, Leupold and others, but very little progress was made. In this year James Watt took out his first patent, dated January 5th, 1769. It was for a method of lessening the consumption of steam and fuel in fire engines. The specification states:—

"First:—That the steam vessel or cylinder must, during the whole time the engine is working, be kept as hot as the steam that enters it; (1st) by enclosing it in a case of wood or any other materials that transmit heat slowly; (2nd) by surrounding it with a steam jacket, or

other heated bodies, and (3rd) by suffering neither water, or any other substance colder than the steam, to enter or touch it during that time.

Secondly:—In engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam vessels or cylinders, although occasionally communicating with them. These vessels are called condensers, and whilst the engines are working, these condensers ought, at least, to be kept as cold as the air in the neighborhood of the engines, by the application of cold water or other cold bodies.

Thirdly:—Whatever air or other elastic vapor is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam vessels or condensers by means of pumps, wrought by the engines themselves, or otherwise.

Fourthly:—I intend, in many cases, to employ the expansive force of steam to press on the pistons, in the same manner as the pressure of the atmosphere is now employed in common fire (atmospheric) engines. In cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the open air, after it has done its office.

Lastly:—Instead of using water to render the pis-

ton or other parts of the engine air or steam tight, he afterwards employed a packed piston working in a bored cylinder."

The great and valuable improvement, described in this specification, is that of condensing in a separate vessel, and it necessarily involved a method of clearing the condenser of air and water. The application of the principle could only be rendered perfect by keeping the cylinder as hot as the steam, and the condenser as cold as it could be done with economy.

The discoveries embraced in Watt's first patent were made when he was a mathematical instrument maker in Glasgow University, A. D. 1765. But it was not until 1769, when Dr. Roebuck of the Carron Iron Works joined him in partnership, for the construction of such engines and a patent was taken out, that an experimental engine was constructed.

In the first trial this machine more than fulfilled Watt's anticipation; its success was complete. In the practical details of its construction, however, some difficulties were still encountered, the greatest of which consisted in packing the piston so as to be steam tight.

While Watt was endeavoring to overcome the difficulties, his partner, Dr. Roebuck, became embarrased, and he was unable to supply the means of prosecuting the projected manufacture of the new engines. The

important results of Watt's labors, however, having become more publicly known, Mr. M. Boulton, of Soho, near Birmingham, proposed to purchase Dr. Roebuck's interest in the patent. This arrangement was effected in 1773, and in the following year, 1774, Watt removed to Soho, and then the famous career of Boulton & Watt commenced.

Watt obtained also an act of Parliament, A. D., 1775, for prolonging, for the period of twenty-five years, the exclusive term vested in James Watt by the patent of 1769. About the year 1776, Watt invented a tubular condenser, with the view of condensing the steam drawn off from the cylinder without the process of injection. These tubes were surrounded by water, and the steam from the cylinder passing through them was condensed by their cold surfaces, and so no atmospheric air could be introduced into the condenser to injure the vacuum.

Thus protected and supported, Watt now directed his mind to perfect the practical details of his invention, and the result was, the construction on a large scale of the engines which have been called his Single Acting Steam Engines. At this time the steam engine had never been employed for any other purpose save that of raising water by working pumps.

From 1750 to 1780 Smeaton applied himself with great success to the improvement of wind and water

WATT.

BOULTON.

mills, and succeeded in augmenting their useful effect two-fold, with the same amount of water. He also made many improvements on Newcomen's atmospheric engines, increasing their power and duty, and often used them as returning engines for the permanent and regular means of supplying water wheels for mills. These improvements obstructed for a time the extension of steam power to mill work, but the increase of manufactures soon created a demand for power greatly exceeding what could be supplied by such limited means. For several years after the extension of Watt's first patent by Parliament, he was occupied in perfecting and constructing his engines for the drainage of mines, and in overcoming obstacles to their general adoption. When, however, these were overcome and the works for the manufacture of pumping engines, at Soho, had been organized and brought into active operation, he turned his attention to the adaptation of the steam engine to move machinery, and thereby to supercede animal power and the natural agents, wind and water. Having made his reciprocating engines very regular in their movements, he then considered how to produce rotary motion and thought of the application of the crank, in the manner of the common turning lathe. A model was made which answered his expectations, but having neglected to take out a patent for it, the invention was communicated by a

workman employed to make the model, and a Mr. Pickard, of Birmingham, took out a patent in 1780 for the application of the crank, and this prevented Watt, for a time, from using his own invention. In these circumstances, he thought it better to accomplish the same end by other means, than to enter into litigation. Accordingly in 1781, October 25th, he invented and took out his second patent for several methods for producing rotative motions from reciprocating ones; amongst which was the method of the sun and planet wheels. This contrivance was applied to many engines, and possesses the great advantage of giving a double velocity to the fly-wheel, but at the expiration of Pickard's patent, which restricted the use of the crank, the sun and planet wheel was discontinued in Watt's engine and the crank restored.

Although by these contrivances Watt succeeded in obtaining a continuous circular motion from the reciprocating motion of the steam engine, the machine was still one of intermitting, instead of continuous action. This did not satisfy the mechanical taste of Watt. He soon perceived that if he could devise means by which the piston might be impelled by steam upwards as well as downwards, he would then have continuous action. To accomplish this, it was only necessary to throw the lower end of the cylinder into alternate communication

with the boiler, while the upper end would be put into communication with the condenser, then the piston would be driven continually, whether upwards or downwards, by the power of steam acting against a vacuum. Watt obtained his third patent for this contrivance on the 12th of March, 1782, embracing various methods of applying steam:—

First:—For an expansive steam engine, with six different contrivances for equalizing the power.

Secondly:—The double-power steam engine, in which the steam is alternately applied to press on each side of the piston, while a vacuum is formed on the other.

Thirdly:—A new compound engine, or method of connecting together the cylinders and condensers of two or more distinct engines, so as to make the steam which has been employed to press on the piston of the first, act expansively on the piston of the second, etc., and thus derive an additional power to act either alternately or conjointly with that of the first cylinder. Of the modes of regulating the power of steam engines, the most effective was by letting the regulating valves open fully at first, and shutting them completely when the piston has proceeded only part of the stroke (or cutting off). This method forms the basis of Watt's Expansive Engine, which renders available more of the

power of the steam than when the piston is acted upon by the whole force of the steam through the entire length of the cylinder.

There yet remained another step to complete the mechanism of the double engine, viz: a guide for the piston rod, and this was accomplished by the invention of the parallel motion. This is a combination of levers, one point of which describes a line nearly straight, and to this point the piston rod is connected. This Watt secured by a fourth patent, A. D., 1784. Another part of this patent was for a locomotive engine, by which a wheel carriage was to be propelled on a road.

Watt obtained a fifth patent, A. D., 1785, for a method of constructing furnaces, in which the best principles the philosophy of the period could furnish, are applied to elicit the heat and prevent or consume the smoke, whereby greater effects are produced from the fuel. He also applied to the steam engine the conical pendulum as a governor, the steam gauge, condenser-gauge, and an instrument for ascertaining the state of the steam in the cylinder, called an indicator. In improving the furnace, Watt proceeded nearly on the principle of Argand's lamp. The grate and dead plates were laid in a sloping direction, downwards from the fire-door, at an angle of about 25° to the horizon. The fuel when introduced is laid on the dead plates,

there it is submitted to the process of coking, by which the volatile gases which it contains are expelled, and being carried by a current of air, admitted through small openings in the fire-door, over the burning fuel on the back part of the grate, they are consumed. When the fuel in the front of the grate has been coked, it is pushed back and a fresh feed introduced in front. The coal thus pushed back soon becomes vividly ignited, and by continuing this process, the fuel spread over the grate is maintained in the most active state of combustion at the back part of the grate. This plan is very effectual, with judicious firing, and at the chimney of the boiler at Soho, where it was in use for half a century, smoke was never to be seen. The openings in the fire-door to admit the air were regulated so as to just admit the quantity which consumed the smoke, more would be prejudicial.

Previous to the introduction of Boulton & Watt's engine into Cornwall, Jonathan Hornblower had been one of the principal builders of engines of that district. In 1781 he took out a patent for working an engine with two cylinders of different sizes, by allowing the steam to flow freely from the boiler until it fills the smaller cylinder above the piston, it is then exhausted into the lower end, from there it is expanded into the upper end of the larger cylinder impelling the piston down, then

it flowed into the lower end, and finally into the condenser, leaving a vacuum in the large cylinder. Hornblower's engine met with little success, as it used steam at low pressure, it had a limited expansive power. Besides, he could not use his engine without borrowing Watt's condenser and air pump, cylinder cover and stuffing box, etc.

In the year 1785 Watt had been eleven years at Soho, and was actively engaged in building his single acting pumping engines, and double acting rotative engines with sun and planet wheels instead of a crank. The merits of these engines had become well known, and they were the original type of nearly all the engines used afterwards in steam navigation.

From this date successful efforts began to be made in propelling vessels by steam.

In 1785 James Rumsey, of Va., gave a public exhibition on the Potomac, above Shepherdstown, Virginia, of his discovery that a boat could be propelled by steam up stream against the current. In 1786 John Fitch, of Philadelphia propelled a boat by steam on the Delaware. In August of the following year (1787) Fitch propelled a new and larger boat, on the Delaware, at three or four miles an hour, but the rate of progress was too slow to satisfy the projector. A. D., 1788, on October 14th, a boat, the joint production of Patrick

Millar, James Taylor, and Wm. Symington, propelled by steam, was put in motion on the Lake of Dalswinton in the south of Scotland. A successful experiment, the vessel moved at the rate of five miles an hour. Millar suggested the use of paddle wheels, Taylor proposed the steam engine as the moving power, and Symington constructed the steam engine. The same men, in the following year, fitted up a larger boat, which was tried on the Forth and Clyde canal in December, 1789, and went at the rate of seven miles an hour. During the summer of 1790, the steamboat company which had acquired an interest in John Fitch's invention, ran a steam packet on the Delaware for three or four months, at a speed of about eight miles an hour, from Philadelphia to Burlington and Trenton, also to Chester and Wilmington, but the boat was not a success financially, and was laid up in the Autumn and was never used afterwards. During the next ten years many experiments were tried with steamboats, but nothing of value seems to have been produced.

In 1794 Pickard's patent for the crank expired, and Watt resumed the use of it on his engines. In the year 1800 the extended patent right which had been granted to Boulton & Watt for their improved engine, expired, and at this time Watt retired altogether from business, and the works at Soho were then conducted by the sons

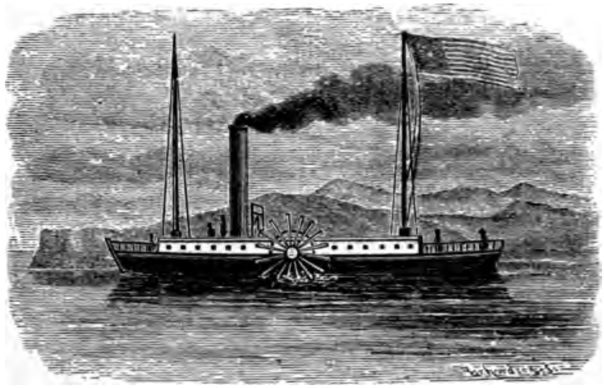
of Boulton and Watt. In 1769, soon after the earlier discoveries of Watt, but before they had come into practical application, Smeaton computed that the average duty of fifteen atmospheric engines (or the number of lbs. one bushel, of 94 lbs., coal would raise one foot high) was 5,600,000. In 1772, Smeaton commneced his improvements and raised the duty to 9,450,000. In 1776, Watt obtained a duty of 21,600,000, ft., lbs. In 1779, Watt reported a duty of 23,400,000 ft., lbs. From 1779 to 1788 Watt introduced the application of expansion, and raised the duty to 26,600,000. In 1798 an engine built by Watt gave a duty of 27,000,000. In 1802, Wm. Symington, who had been associated with Millar and Taylor in the experiment at Dalswinton, constructed a steam vessel for the purpose of superceding the use of horses in towing vessels along the Forth and Clyde canal. This vessel, the "Charlotte Dundas," went steadily at the rate of six miles an hour, and may be considered a complete success, but was interdicted by the canal company, as they feared its motion would destroy the canal banks. The boat was fitted with a stern wheel.

In 1802 Trevethick & Vivian patented and constructed a high-pressure or non-condensing engine, the first of this kind which was brought into extensive practical use. This idea occurred to Leupold in 1720, and

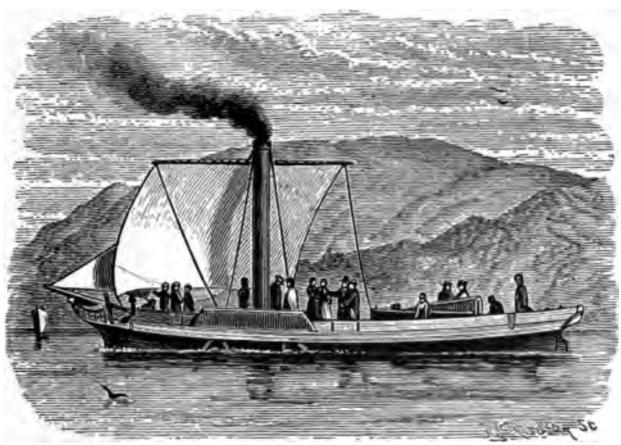
to Watt, but neither of them had reduced their notions to practice. The first trial of this species of moving power for carriages took place on a railroad at Merthyr Tydvil, Wales, in 1805. It was not at that period followed up, but was later. In 1804, Arthur Woolf obtained a patent for the application of steam, raised under a high pressure, to double-cylinder engines. The mode of condensation invented by Watt being now public property, and the term of Hornblower's patent having expired, Woolf adopted the arrangement of the latter, with the alteration of using high-pressure steam in the small cylinder, and employing the condensing apparatus of Watt. The fact that contributed to the success of Woolf's engines, was that although the expansion was not sufficient to yield much advantage over ordinary engines, the division of the work of the steam between the two pistons diminished the differences in pressure and the loss of steam. The first Woolf engine was set up in a London brewery, afterwards Hall made a large number. In 1815 they were introduced into France by Edwards, and they rapidly came into use there, without much change in construction.

In 1805, Willis Earle took out a patent for engines composed of a large and small cylinder superposed (or tandem) with two pistons mounted on the same rod, a device frequently repeated since that time.

In 1807, Robert Fulton, in New York, launched a steam vessel, "The Clermont," 130 ft. long by 18 ft. beam, and 6 ft. depth of hold. The boat was fitted with a Boulton & Watt engine, 24 inches diameter of cylinder and 3 ft. stroke, it was called a square engine, or table engine, and had two connecting rods and cranks. The boiler was a low-pressure, or wagon-shaped one, of the form used with Watt's engines, and set in masonry. The side wheels were 15 ft. in diameter and 4 ft. wide, with two ft. dip. The condenser stood in a large cold-water cistern. The weight of the masonry and the great capacity of the cistern diminished materially the buoyancy of the vessel. The "Clermont" started on her first trip from New York on August 7th, 1807. The speed was about five miles per hour, and several trips were made during the Summer. During the Winter of 1807–8 the "Clermont" was almost wholly rebuilt and much improved. She commenced her trips for the season of 1808, and started regularly at the appointed hour. At the end of the season she proved too small for the crowds who thronged to take passage. The success of the "Clermont" led Fulton & Livingston to build two other vessels, viz: "The Car of Neptune" and the "Paragon" and add them to the line, and from that time to the present, the Hudson river has been the scene of the most remarkable series of experiments of locomo-



"CLERMONT"



"COMET"

tion on water which has ever been presented in the history of navigation. In 1809, February 11th, Fulton took out his first patent for navigation by steam; and February 9th, 1811, he obtained a second patent for some improvements on his boats and machinery. In 1807, Robert L. Stevens, of Hoboken, in conjunction with his father, John C. Stevens, of Hoboken, constructed a paddle-wheel steamer, which was in motion on the Hudson only a few days later than Fulton's first successful voyage. He called her the "Phenix." Precluded, by Fulton's monopoly on the waters of New York, the "Phenix" was employed as a passage boat between New York and New Brunswick, and finally in June, 1809, she went to sea by steam, around Cape May to the Delaware, where she ran from Philadelphia to Bordentown, and belonged to what was called the Swiftsure Line, between New York and Philadelphia. This vessel made the first sea voyage by steam.

Prior to the practical working of any steamboat in Europe, Charles Brown, on the East river had built for Fulton the following vessels: "Clermont," in 1806; "Raritan," 1807; "Car of Neptune," 1807; "Paragon," 1811; "Jersey Ferry Boat," 1812, and "Fire Fly," 1812. In 1812, Henry Bell placed a steamer called the "Comet" on the Clyde to ply between Glasgow and Greenock. This vessel was built by John Wood, of

Port Glasgow, and was 40 ft. keel, and 10½ ft. beam, and had a three-horse power engine, built and fitted on board by John Robertson, of Glasgow. The vessel made a speed of about five miles an hour, and continued, during the Summer to ply successfully as a passenger boat. In the following year, 1813, the "Elizabeth," built by John Wood, and engine by John Thompson, was started for passengers on March 9th and averaged a speed of nine miles an hour. This vessel was very successful and brought much profit to the owner. The "Comet" heralded the way to rapid improvements, and the years 1815 to 1820 gave us ocean-going steamships. Soon after the introduction of steam on the Clyde, David Napier of Glasgow entertained the idea of establishing steam communication on the open sea. He commenced a series of experiments with models of vessels, so that he could decide on a suitable model. This led him to adopt the fine wedge-like entrance, by which the vessels built under his superintendence were afterwards so distinguished. In 1818 he established a regular steam communication between Greenock and Belfast by means of the "Rob Roy," a vessel of about ninety tons burden, and thirty-horse power. She plied two years between these ports with success, and afterwards was transferred to the English Channel as a packet between Dover and Calais. In 1819, J. Wood built for D.

Napier, the "Talbot," one hundred and fifty tons, with two of his engines, each thirty-horse power. She was the most perfect vessel of her day in all respects. The "Talbot" plied between Holyhead and Dublin and conferred on Ireland rapid communication. D. Napier in 1822 introduced surface condensers on the "Post Boy," a steam vessel built by him, to enable him to use fresh water in the boilers. He introduced the side-lever engine, for sea-going, and the steeple engine, for river vessels, and the double-crosshead, direct-acting engine. In 1820–23, the "Comet," "Lightning," and "Meteor," the first steam vessels in the British navy, were built at Deptford, London, by Oliver Lang, and fitted with side-lever engines by Boulton & Watt. In 1822, Wood built, on the Clyde, the "James Watt" and "Soho," to run between Leith and London, the engines being from the works of Boulton & Watt. In 1826, the "United Kingdom" was built for the trade between London and Edinburgh. She was 160 ft. long, with 26½ ft. beam, and had engines of 200-horse power built by David Napier. She was considered the wonder of the day, aud people flocked to see and admire her.

In 1822, Robert Napier commenced to build marine engines. He had been in bnsiness some seven years as a blacksmith, millwright, engineer, and ironfounder, but he had never built any marine engines. In this

year he associated David Elder with him as his foreman and manager. This connection existed for nearly half a century. Napier's first contract was for the engines of the "Leven," (a steamer intended for the trade between Glasgow and Dumbarton) which was designed by Elder, and in succession the engines and boilers of the "New Dumbarton", "Sultan", "Greenock", "Helensburgh", "Clarence", "Ardincaple", "Eclipse", etc., were turned out from the workshops of Napier. He soon after moved to the Vulcan Foundry, Glasgow, and also succeeded his cousin, David Napier, at Lancefield Foundry, about 1830, who then went to London. The admirable designs and the accuracy of the workmanship which Elder introduced into marine engineering soon raised the character of the establishment of which he was manager, and orders came flowing in from all quarters. He was said to have been the first to apply expansion valves to steamers.

In 1828, M. Seguine obtained a patent for the modern (fire) tubular boiler, dated February 22nd, 1828, and in the following year, 1829, George Stephenson brought out his celebrated locomotive, Rocket, on the Liverpool and Manchester railroad, which had a cylindrical boiler 6 ft. long, and 3 ft., 4 in. in diameter, with a fire box 2 ft., 3 in. broad, 3 ft. long and 3 ft. deep, having a 3-inch water space. In the boiler were twenty-five 3-inch

fire tubes. The suggestion of using these tubes was due to Booth, the treasurer of the railroad company, and the superiority of the Rocket was due chiefly to the greater amount of fire surface which the tubes furnished, and the trial of it settled decisively the future career of the locomotive engine, and from this time the locomotive went steadily forward.

In 1831, James and William Napier, of Glasgow, patented their return tubular boiler, with a large back connection or combustion chamber, commonly called the "Scotch boiler", in which the tnbes are placed over the furnaces. And before the patent was sealed, the patentees contracted to supply boilers to the Clyde Shipping Company's steamer, "Aimwell". These boilers gave good satisfaction, and were the precursors of the modern return tubular boilers. They admit of a large amount of grate and fire surface in a limited space, which, of course, is most important on board a steam vessel.

CHAPTER II.

In 1815, the "Chancellor Livingston" was constructed under the superintendence of Fulton, in New York, to run on the Hudson. She was not launched until after his death, and may be considered the crowning effort of his life. She was 496 tons burden; keel, 154 ft. long; decks, 165 ft.; beam, 32 ft.; draft, 7 ft., 3 in.; paddle wheels, 17 ft. diameter, by 5 ft., 10 in. wide; engine, 75-horse power; cylinder, 40 in. in diameter, by 5 ft. stroke; boiler 28 ft. long and 12 ft. broad, with two smoke pipes. She had two fly wheels, each 14 feet in diameter, connected by pinions to the crank wheels. The machinery rose 4 ft. above the deck. Her average speed was 8.5 miles per hour. She was afterwards lengthened, and with a larger engine her speed was increased. In 1832 she was bought by C. Vanderbilt and A. H. Cross, of Portland, and put on the route

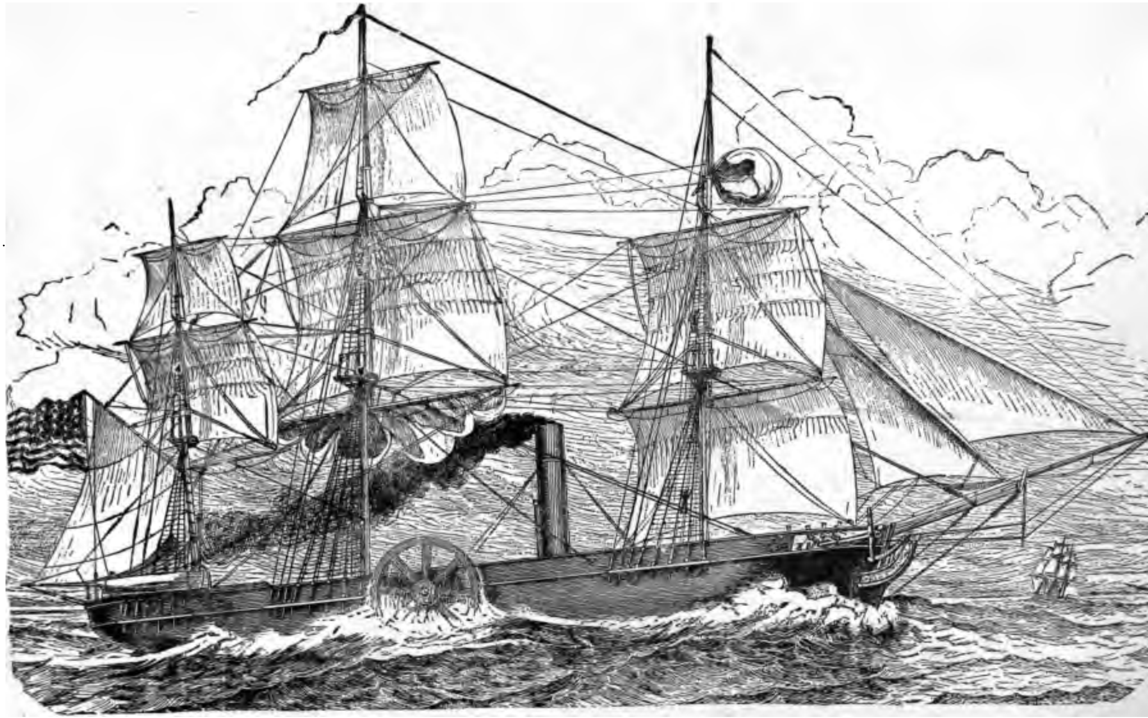
between Boston and Portland, as an opposition boat. At that time she had in her third engine, which was what was called a square or cross-head engine; walking beams had not then came into use. This engine had a 56-in. cylinder and 6-ft. stroke. It was the custom, with square engines, to have large crank wheels on the centre shaft, with gear teeth on their rims, and these were geared to pinion wheels on the fly wheel shafts, as it was thought the cranks would not pass the centres without a fly wheel to help them past.

In 1825 to 1828, James P. Allaire, of New York, adopted the Woolf double-cylinder engine on the steam boats "Henry Eckford", "Sun", "Commerce", "Swift-sure", "Post Boy", and "Pilot Boy". They were built on the square-engine design, the low-pressure engine being connected to what was before, the fly-wheel shaft, and so geared to the high-pressure engine. The paddle shafts had cranks and their pins connected them to the crank wheels on the centre shaft. The D-slide valve was used on the engines and the high-pressure steam of 125 to 150 lbs., generated in the Redfield boilers, caused trouble and delay in starting and stoping. Sometimes the boats would run into one another or run into the dock. The teeth on the gear wheels sometimes broke and caused trouble and they went out of use. The fly wheels were also dispensed with on the

square engines, balanced poppet valves and a cut off were applied, and some of them are still in use.

In 1814, the first war steamboat, "Fulton", for the United States navy, was built on Fulton's design, by A. & N. Brown, of New York, and launched on October 18th, of that year. Length, 150 ft.; breadth, 56 ft.; depth, 20 ft.; water wheel, 16 ft. diameter by 14 ft. wide, dip 4 ft.; engine, 48-in. cylinder by 5-ft. stroke; boiler, 22 ft. long by 12 ft. broad and 8 ft. deep; tonnage, 2,475. The structure rested on two boats, keels separated from end to end by a canal 15 ft. wide, and the water or paddle wheel between them. The boilers were placed in one boat and the engines in the other. She was fitted with guns for coast and harbor defense, was tried on July 4th, 1815, and her speed was about 5 miles an hour. When the various tests of her powers had been made the war had terminated, and the "Fulton" was taken to the Brooklyn navy yard, where she was used as a receiving ship until June 4th, 1829, when she was accidentally blown up, killing many people.

In 1816, Capt. N. Bliss, of Hebron, Conn., who had been intimate with Fulton, and who had been engaged in building a steamboat at Philadelphia, went to Cincinnati, and there in the following year he engaged, with the eldest son of Gen. W. H. Harrison, in the construction of steamboats. They built the "Gen. Pike", which



S. S. "Savannah"

Capt. Bliss afterwards claimed was the first steamboat built on the Ohio river. He returned to New York in 1827, and soon afterwards with Dr. E. Nott, formerly president of Union college, he engaged in experiments in steam navigation. In 1831, he established the celebrated Novelty Works, where the machinery for many ocean steamships and steamboats was since constructed.

A. D., 1819, the "Savannah", the first steamship to cross the Atlantic ocean, sailed from Savannah on the 26th of May, and reached Liverpool on June 20th, having been 14 days under steam, the rest of the time under sail, as they feared the fuel might give out. The vessel was built at Corlears Hook, New York, by Croker & Fickett. She was 380-tons burden, and was launched on the 28th of August, 1818, and built to ply between New York and Liverpool as a sailing packet. William Scarborough & Co., of Savannah, purchased this ship and named her the "Savannah". They allowed the rigging to remain and fitted her with machinery, and paddle wheels constructed to fold up like a fan, and to be laid on deck when not in use, her shaft having a joint for that purpose. The wheel house was made of canvas extended on an iron rim. The engine castings were made at the Allaire Works, New York, and the boilers at Elizabeth, New Jersey, by Daniel Dodge. After leaving Liverpool this ship visited Copenhagen,

Stockholm, St. Petersburg, Cronstadt, Arendal, in Norway, and from thence went to Savannah in 25 days, steaming on the passage 19 days. Afterwards, at the suggestion of President Monroe, the owners sent her to Washington in the hope of selling her for a cruiser, but the government did not buy her. She was there sold at auction and converted into a packet. After being used for a time as a sailing packet between New York and Savannah, the "Savannah" went ashore on Long Island and was broken up. The steam cylinder of the vessel lay around the Allaire Works for many years, and was accidentally broken up. It was said that Scarborough ruined himself by this ship and died poor.

In 1816, Robert L. Stevens commenced steam ferriage between New York and Hoboken; in 1818 he discovered the utility of using steam expansively, and using anthracite coal for fuel in steamers; in 1821 he substituted the skeleton wrought iron for the heavy cast iron walking-beam, and in 1824 applied an artificial blast to the boiler furnace, and in 1827 the hog-frame to boats to prevent them from bending at the centre.

In 1811, the "New Orleans," built at Pittsburgh, by Fulton, Livingston & Roosevelt, went from that city to New Orleans. The size and plan of this steamboat was furnished by Fulton. It was 116 ft. long and 20 ft. beam. The engine had a 34-in. cylinder, and the boiler

etc. in proportion. This was the first steamboat to descend the Mississippi, and the first to ascend was the "Enterprise" in 1815. After this steamboats rapidly increased in number on the western waters. They usually had high-pressure, horizontal engines, and cylindrical or Cornish boilers, carrying steam of 100 to 150 lbs. pressure.

In 1822 a company was formed called the "Rhode Island and New York Steamboat Company", and regular trips, twice a week, were begun by the "Fulton" and "Connecticut". These trips were continued through the season, and thus was inaugurated the steamboat trade between New York and Providence. Similar trips were made in 1823.

Until the year 1834 steamboats in the United States had burnt wood only. In 1836 experiments were made with anthracite coal for fuel on board the ferryboats in New York with success. In 1835, Capt. Coyle, then the engineer of the steamer "Portland", is said to have invented a blower by which he was able to use anthracite coal on board the "Portland", and she was said to be the first steamer that burnt anthracite coal with success. Small blower engines were soon after adopted in New York. The advent of ocean steam navigation soon led to the almost universal use of coal (bituminous and anthracite); even the steamboats on the Mississippi

have adopted the former. From 1830 to 1840 beam engines were generally adopted in the Eastern States, and on the lakes for steamboats. Fulton had adopted the square engine, but R. L. Stevens retained the beam engine of Watt, placed the condenser below the cylinder, on a bed plate with the air pump, and supported the beam by a wooden gallows frame. He also introduced a very long stroke of the piston. This involved a smaller diameter of cylinder, lighter connections, longer crank, and larger diameter of paddle wheel which acted more favorably on the water. The parallel guides were also substituted for the parallel motion. The next great improvement that was effected in American engines is the application of the principle of expansion. The practice of the Cornish engineers, who used the expansion principle, was known, and Adam Hall, then of West Point Foundry, N. Y., was said to be the first who conceived the idea of using high-pressure steam on the beam engine and cutting off the supply at ¾, ½, or even ¼ of the stroke, anticipating a saving in fuel, and an increase in velocity. It was found by experiment, and established by practice, that more work was done at less expense, by cutting off at ¼ than by cutting off at ½ the stroke; the steam pressure being, of course, increased in proportion. The method of working expansively with a long stroke engine, and large balanced

valves and passages, has allowed a high velocity of piston, 600 feet per minute is common.

The steam jacket of Watt was seldom adopted, but the high steam chimneys on the boilers (said to have been first introduced by James P. Allaire) were an equivalent, when steam of not over 40 lbs. was used, which was the practice then, the chimney acted as a separator, to separate the water in suspension in the steam, by gravity, and it also superheated the steam to a moderate degree. At this period, the fly valve, placed close to the steam chest in the steam pipe, and operated by a cam motion, was used as an expansion valve. Such an engine, compared to what had been used before, developed a great amount of power with a good degree of economy, and with a reduced weight of engine.

From 1840 to 1850 steamers began to cross the Atlantic; the Mexican war broke out and continued from 1845 to 1848; the discovery of gold in California in 1847, and the political transfer to the United States in 1848, taken together, gave a great impetus to steamboat and steamship building. Beam engines of much greater dimensions for river, lake, and coasting trade, side-lever and oscilating engines for ocean steamships, and inclined and side-lever engines for the navy were built extensively. A good specimen of the earlier beam engine is that of the "Osceola", cylinder, 34 in. diameter by 11

ft. stroke; constructed by Adam Hall, of New York, and illustrated in the Practical Mechanic and Engineer's Magazine, Glasgow, 1845. This engine had the fly-valve cut-off. During this period R. L. Stevens introduced his long-toe cut-off, which came to be extensively used, and was usually fixed to cut off at about ½ stroke, and the speed of the engine was regulated by the throttle valve. In contrast with this, F. E. Sickels introduced his celebrated adjustable cut-off, as applied to balanced poppet valves. In this design the steam valve can be tripped and closed at any part of the stroke, and is adjusted when the engine is working. It can also be used instead of the throttle to control the speed of the engine. The valve stems are detached from the valve gear, and the fall of the valves is controlled by dash-pots, so that they may not slam on the seats though they fall quickly, and close the valves almost instantaneously. This gear when properly adjusted works very nicely, and gives an ideal indicator diagram. It also, when properly applied and worked, secures great economy in fuel.

Allen & Wells, of the Novelty Works, New York, introduced their cut-off, intended to produce the same result as the Sickles cut-off, and this was applied in many cases successfully. Herman Winters, then at the Morgan Works, also introduced his cut-off with a revolving

shaft and cams, which was used in a good many cases and with good results. But none of these cut-offs had the range or produced the instantaneous cut off that the Sickles' cut-off did.

A good example of the condensing beam engine built at this time is the "New World's" engine, built by T. F. Secor & Co., designed by Edward Tothill, and illustrated in Tredgold on the Steam Engine, London, 1851. The cylinder is 76 in. diameter by 15 ft. stroke; paddle wheels, 45 ft. diameter by 12 ft. face; return, round-flue boilers; steam pressure 45 lbs. cut off at 8 ft. by a Stevens cut-off gear, and the boilers have a fan blast under the grate; consumption of anthracite coal per hour, 9,000 lbs.; average number of revolutions per minute, 17. This engine was afterwards put in the steamboat "St. John", in 1863, and the cylinder increased to 84 in. diameter. The most noted beam engines built during this period were the "Bay State" and "Empire State" for the Fall River Line to Boston: Cylinders 76 in. diameter by 12 ft. stroke; return-flue boilers on the "Bay State" and drop-flue on the "Empire State". Both carried 25 lbs. steam, with Stevens' cut-off at half stroke. The "Empire State" had Sickles' cut-off fitted afterwards. The "Isaac Newton" cylinder, 81 in. dia. by 12 ft. stroke, and return-flue boilers; steam, 35 lbs., with Stevens' cut-off at ½ stroke; for

the New York and Albany Line. The "Empire State", with 76 in. cylinder by 12 ft. stroke; steam, 30 lbs., and the "Buckeye State", with an annular engine; cylinders, 37 in. and 80 in. in diameter by 11 ft. stroke; return tubular boilers; steam, 75 lbs. pressure; the steam was first used in the small cylinder and then expanded into the large one. Both of these engines were designed by E. W. Smith, of New York, and ran on Lake Erie. In the decade before 1850, the side-lever engines for the "Georgia" and "Ohio" were built, by T. F. Secor & Co., designed by Edward Tothill; cylinders, 90 in. diameter by 8 ft. stroke; round-flue boilers; steam pressure, 15 lbs., cut off at 4 ft. with Stevens' cut-off; ran between New York and New Orleans. They were well proportioned, strong, serviceable engines, and in some respects resembled the Cunard engines in use at that time. They were illustrated in Tredgold, 1851.

The side-lever engines of the Collins Line Steamers, "Atlantic", "Artic", "Pacific", and "Baltic", were built in 1849–50; the two former at the Novelty Works, and the two latter at the Allaire Works, New York. The engines were designed by C. W. Copeland, and the boilers by John Faron, chief engineer of the line There were two engines in each ship, with cylinders 95 in. dia. by 9 ft. stroke in the "Atlantic" and "Pacific", and

95 in. diameter by 10 ft. stroke in the "Artic" and "Baltic". The boilers had two tiers of furnaces and vertical water tubes back of them, and the four boilers connected to one smoke pipe. The steam pressure was 14 lbs., and cut off with Stevens' cut-off and Sickles' on the "Baltic", at 4 ft. and 4 ft. 6 in. respectively.

With using salt water, the scale in the tubes was troublesome, and the unequal expansion of the front and back tubes caused them to leak, so that the expense for cleaning and repairs was heavy. The unequal expansion of the parts of the engine, due to the design of the bracing, caused breaks and consequent expense, yet the engines did good service, the ships made good voyages and with reasonable economy of fuel.

The engines of the steamer "America", on the Lakes at this time, running between Buffalo and Chicago, are typical western river engines. They are slightly inclined, cylinders 30 in. diameter by 11 ft. stroke; steam pressure 90 lbs. cut off by cam at 4 ft. 2 in.; seven return flue boilers on deck 3 ft. 6 in. in diameter by 30 ft. long, with two return flues 16 in. diameter in each, all set in brickwork inside a sheet-iron case, built at Cincinnati. There was an engine and paddle wheel at each side of the boat, and each independent of the other, so that one can be backed when the other is going ahead, or they work together as de-

sired, so that they can turn the boat easily.

Another example of marine engines for ocean steamers were the oscillating engines of the "Golden Gate" built at the Novelty Works, and of the "Illinois" built at the Allaire Works, New York: there were two in each ship, cylinders 85 ins. diameter by 9 ft. stroke: they had slide valves, worked by link motion gear for reversing and backing: the boilers were return tubular, steam pressure 14 lbs. the cut-off was by the link motion only, the engines worked hard by hand, and a small pair of reversing engines were applied on the "Illinois".

The ships ran on the California route from New York to San Francisco: the "Golden Gate" on the Pacific, and the "Illinois" on the Atlantic.

Inclined engines were adopted on the Union Ferry from New York to Brooklyn before 1850. They worked well, took up little deck room, and were not much affected by the jarring of the boats when making a landing.

Drop flue boilers were generally used with them, steam about 15 lbs. pressure, cut off at half stroke by a Stevens cut-off, a fresh water tank was used to feed the boilers from and the tank was filled from the Croton (City) water pipes.

Before 1850, the principal steamers which had been built for the United States Navy were the "Princeton' 663 tons, designed by John Ericsson, 164 ft. long by 30

ft. 6 in. beam, constructed in 1843. She had two semi-cylindrical engines with vibrating pistons, and three iron flat flue boilers, with fan blast under the grate, all below the water line. Propellor 14 ft. diameter by 35 ft. pitch, 24 revolutions per minute, speed about 9 miles per hour.

The "Massachusetts", 779 tons, engines and boilers designed by John Ericsson, built by Hogg & Delamater, New York. Two inclined engines, cylinders 25 ins. diameter by 3 ft. stroke, two iron return tubular boilers, steam pressure 40 lbs., cut off at half stroke, draft produced by an exhausting fan in the chimney: propellor 9 ft. 6 ins. diam. by 20 ft. pitch, revolutions per minute, 50.

The "Susquehanna", 2436 tons, engines and boilers designed by C. W. Copeland, two inclined engines, direct acting, cylinders 70 ins. diameter by 10 ft. stroke, steam pressure 10 lbs., cut off at 6 ft. by Steven's cut-off, paddle wheels 31 ft., 2 ins. diam. by 9 ft. 6 in. face, revolutions per minute, 12, four copper flue boilers.

The "Mississippi", 1788 tons, engines and boilers designed by C. W. Copeland, two side lever engines, cylinders 75 ins. diam. by 7 ft. stroke, steam pressure, 12 lbs. cut off at 3 ft., paddle wheels 28 ft. diam. by 11 ft. face, revolutions per minute, 11, four copper flue boilers.

The "Saranac", 1426 tons, engines and boilers designed by C. W. Copeland, two inclined engines, direct acting, cylinders 60 ins. diam. by 9 ft. stroke, steam pressure 14 lbs., cut off at 3 ft. 6 ins., paddle wheels 27 ft. 6 in. diam. by 9 ft. face, revolutions per minute, 13, three copper drop flue boilers side by side.

The "Michigan", 518 tons, on Lake Erie, engines and boilers designed by C. W. Copeland, two inclined engines direct acting, cylinders 36 ins. diam. by 8 ft. stroke, steam pressure 15 lbs. cut off at 3 ft. 6 ins., paddle wheels 21 ft. 10 ins. diam. by 7 ft. 6 ins. face, revolutions per minute, 22, two iron return flue boilers, side by side. This vessel was afterwards fitted with two Martin water-tube boilers, and had Sickles cut-off, when the experiments were made at Erie, Penn., to determine the relative economy of using steam with different measures of expansion, with a steam pressure of 21 lbs. per sq. in., cutting off at 4–45 to 11–12 of the stroke.

The "Water Witch" is 131 ft. long by 19 ft. beam, by 9 ft. 9 in. deep, engine and boiler designed by C. H. Haswell, inclined back acting square engine, cylinder 37.5 ins. diam. by 6 ft. stroke, paddle wheels 16.5 ft. diam. by 6 ft. face, return tubular boiler, cut-off adjustable.

The "Powhattan", 2419 tons, engines and boilers designed by C. H. Haswell, two inclined engines, cylin-

ders 70 ins. diam. by 10 ft. stroke, paddle wheels 31 ft. diam. by 10 ft. face, four copper flue boilers.

The "San Jacinto", 1426 tons, engines and boilers designed by C. H. Haswell, two inclined engines, geared 22–7 to 1, cylinders 62½ in. diam. by 50 ins. stroke, revolutions per minute, 30, propellor 14 ft. 6 ins. diam. by 40 to 45 ft. pitch, steam pressure 15 lbs., three copper-flue boilers side by side.

In these U. S. Naval steamers it will be observed, that there was no effort made to produce economy of fuel beyond the ordinary half-stroke cut-off; neither high pressure steam, high chimney to superheat, nor steam jacket to prevent cylinder condensation.

CHAPTER III.

In 1834 Earnest Wolff took out a patent for an engine described as compound, which indicates the possibility of modifying existing engines so as to adapt them to the new mode of action.

The invention consists of the combination of two or more engines, each complete in all its parts, and so disposed that while the first receives steam at one, two, or more atmospheres, the next engine is moved by the steam that escapes from the first. In the last engine the steam is condensed in the ordinary way, or escapes into the atmosphere. The work supplied by the several engines is applied to the same shaft, or to several combined, or to independent shafts. As in steam vessels and other applications, two conjoined engines are generally employed. The present invention is especially adapted for this purpose, as it presents economic advan-

tages, and it reduces the expense of the apparatus without increasing its complication. It is sometimes useful to have between the cylinders an intermediate reservoir to regulate the pressure. This may be placed with advantage at the base of the chimney, so as to maintain or raise the temperature and the pressure of the steam in its passage from one cylinder to the other. Indeed if necessary, the heat may be supplied by a special firebox. It is often necessary to employ a special pipe with a stop-cock, to admit the steam from the boiler to an intermediate reservoir, in order to give to the machine the power of starting any crank. This direct introduction may be employed to increase, for a time, the power of the engine. The writer then explains a method of modifying old engines by adding to a high-pressure engine a low-pressure cylinder; or, in the case of a marine engine, by substituting for one of the low-pressure cylinders a high-pressure cylinder. The drawing annexed to the patent shows a pair of marine beam engines. This patent seems to have anticipated the compound engines afterwards built so extensively.

In 1842, Hinrik Zander took out a patent for an engine, in which the steam acts in the first cylinder expansively, to a certain extent, then passes into the two others, which are larger, and expands. The three cylinders are attached to the same shaft, so that their mo-

tion may be as uniform as possible. The low-pressure cylinders are provided with jackets which contain the steam from the boiler. Zander describes intermediate reservoirs, and proposes to introduce into them, or into a communicating pipe supplying their place, a float-valve to allow the escape of condensed water. In his drawings is represented a disposition in which the crank of an oscillating, high-pressure cylinder, placed obliquely, is attached to the crank of a marine beam engine. This engineer seems, according to documents found, to have built some marine engines on this plan. This patent seems to have anticipated the three-cylinder and the three-crank engines, since built so extensively.

In 1844, Octavius Henry Smith patented an engine acting on the Woolfian principle, consisting of a high-pressure and a low-pressure cylinder, both oscillating and having their rods attached to the same crank. The "Cricket" engine, on the Thames, was of this kind. A description of it was given in the Practical Mechanic and Engineers' Magazine, 1846. This boat was built and engines fitted by W. Joyce & Co., of Greenwich; speed, 14 miles an hour; consumption of coal, 4½ lbs. per indicated horse power per hour. The boiler was a Napier return tubular, but appears to have been recklessly managed, and it exploded, killing the fireman and injuring many others. This accident placed a dam-

per on the introduction of high-pressure steam for a time.

In 1845, Wm. McNaught patented a form of compound engine, in which a high-pressure cylinder was applied to an ordinary beam engine. He attached the high-pressure cylinder to the beam, on the end opposite to that on which the low-pressure cylinder was connected, and the steam after being used in the usual way in the high-pressure cylinder, passed into the low-pressnre cylinder, after which it escaped into the condenser. An engine of this kind was illustrated in the Practical Mechanic and Engineers' Magazine, of 1846. The proportion of the cylinders was 4 to 1; the steam pressure, 30 to 40 lbs., and the consumption about 4½ lbs. coal per indicated horse power. Many engines were changed to this plan, and many new ones were also built on it.

In 1841, J. G. Bodmer, of Manchester, obtained a patent for his double-piston, compensating, locomotive engine, with balance cranks and hollow piston valves, with cylindrical cut-off valves inside, controlled by right and left screw. An illustrated description was given by Bodmer in the Practical Mechanic and Engineers' Magazine, of 1846 and 1847. There was also a compensating, marine engine shown with double cranks, surface condenser, centrifugal circulating pump, piston

valve, cut-off valve controlled by right and left screw or valve stem. A modification of this idea was patented in the United States by Wallace Wells, called the Wells balanced engine. Another modification was also used on the United States steamer "Pensacola" by Dickerson & Sickels. In 1842, Meyer effected an important improvement. He formed the idea of causing the expansion valves to work on the back of the steam valves, so as to obtain a considerably quicker cut-off. Retaining Bodmer's ingenious right and left screw spindle, Meyer produced the gearing represented in the Practical Mechanic and Engineer's Magazine, of September, 1846, which soon came into use, and is still extensively used on stationary and marine engines. The steam slide valve is merely a flat plate provided with two end ports and a central exhaust cup, as used in ordinary valves. The cut-off plates work steam tight on the back of the steam slide valve, and their relative distance is adjusted by the right and left screw on the valve stem. This gear is adjustable when the engines are working, and there is a hand or worm wheel on the cut-off valve stem for revolving it, and an index for showing the point of cutting off the steam.

In 1838, John Bourne took out a patent for using high-pressure steam expansively in steam vessels, in which plan the feature of external condensation was in-

troduced. He proposed to use the locomotive form of boiler with brass tubes 2½ in. diameter. The steam was to be cut off by a slide valve formed of two movable plates worked on the back of the common slide valve; and the degree of expansion was regulated by a right and left hand screw, which drew the plates nearer together, or separated them further apart, according as much or little expansion was desired. The spindle on which the screws were cut passed through a stuffing box, and was armed at the top with a small wheel, by turning which the amount of expansion was determined. Bourne believed this was the first example of a class of expansion valves, which has come into extensive use since. He proposed to condense the steam by sending it through a number of small copper tubes immersed in cold water.

In 1836, the Cornish, single-acting, condensing engine at Holmbush, cylinder 50 in. diam. by 9 ft. stroke, steam at 30 lbs. pressure, and cut-off at 1–6 stroke, burned 112 lbs. of Welch coal to raise 140,484,000 lbs. one ft. high. This shows a great improvement over Watt's engine of 1798, which, as we have seen, burned 94 lbs. of coal for a duty of 27,000,000 ft. lbs. or raised one foot high. J. Bourne says: "The Cornish engines are always provided with a steam jacket, supplied with steam direct from the boiler. That Watt in his early

practice, discarded the steam jacket for a time, but returned to it again, as he found its discontinuance occasioned a perceptible waste of fuel, and in modern engines it has been found that where a jacket is used, less coal is consumed than where the use of a jacket is rejected." The grand secret however, of the economy of of the Cornish engine lies, first, in the use of high-pressure steam cut off when a very small part of the stroke has been performed, and working expansively over the remainder; second, in the steam jacketing and careful clothing with non-conducting material, of every part of the engine where heat can escape; third, the excellent system of registering and publishing the duty of each engine which has been prevalent in Cornwall. It has made both the proprietors and engineers much more careful than they otherwise would have been. The results obtained were very little aided by any peculiar excellence in the boilers.

At the British Association meeting, at Manchester, in 1842, during the discussion of Mr. Fairbairn's report on the combustion of coal and the prevention of smoke, Capt. Taylor, of Cornwall, spoke as follows: He referred to the statement in Mr. Fairbairn's report, that the average consumption of coal in Manchester was 10½ lbs. per horse power per hour, while in Cornwall it was only 2½ lbs. Although in Cornwall they had none of

those ingenious devices for burning smoke, they allowed very little to escape, and made 1 lb. of coal do as much as 4 lbs. were made to do in Manchester. In the parish of Guennap there were twenty-five chimneys, of which he had eighteen himself, and not a particle of smoke could be seen. All the engines were, besides, of a very large power, but the boiler space was greater and more care was taken in the firing. As to patents for coking the coal, that had been the duty of every careful fireman in Cornwall, for the last twenty years. It was, however, to be observed that the kind of work done by the engines was of such a nature that the amount done with a given quantity of coal could readily be ascertained. In consequence of this, the system had been introduced of weighing out the coal regularly to the firemen, and the duty of the engines was reported every week, and, at some mines, every day. This produced, simultaneously, an emulation among the engine-makers, the proprietors, and the workmen, each of whom was ashamed of being outdone by his neighbors; and, from their joint care and exertions, and most especially that of the firemen, resulted that extraordinary economy for which the Cornish engines are so justly famed. The plan followed was to keep their fires bright, coking the coal in front, and when sufficient boiler space was given, and proper management insured, no smoke-con-

suming patents were necessary; and he felt fully persuaded that if the proprietors of steam engines in Manchester would attend to the Cornish principle, they would find their smoke consumed and much gross waste of fuel prevented.

About the year 1811, a number of the proprietors of the principal Cornish mines agreed to establish a system of inspection, under the management of Capt. Joel Lean, and to publish monthly reports. In these reports were stated, with other particulars, first, the consumption of coal in bushels; second, the duty of the engine expressed by the number of pounds raised one foot high by the consumption of one bushel of Welch coal of 94 lbs. When these reports were commenced, the number of engines brought under inspection was 21; in 1814, thirty-two; in 1820, forty; in 1828, fifty-seven, and in 1838, sixty-one. This gradual increase in the number of engines brought under this system of inspection was produced by the good effects which attended it. These beneficial consequences were manifested, not only in the improved performance of the same engines, but in the gradually improved efficiency of those which were afterwards constructed.

The following, taken from the statement of the duty of Cornish engines by Thomas Lean and brother, published by the British Association, will show in a striking

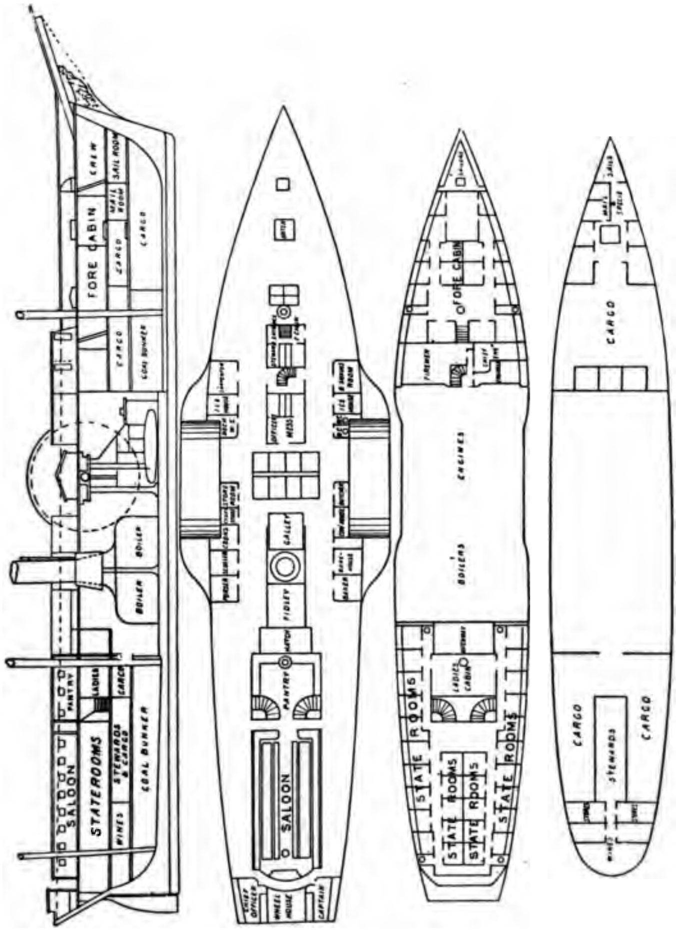
manner, the improvement of the Cornish engines, from the commencement of this system of inspection up to 1838. In 1813 the average duty of the best Cornish engine was 26,400,000 ft. lbs., or raised one ft. high by the consumption of one bushel of Welch coal of 94 lbs.; in 1818, the duty was 39,300,000 ft. lbs; in 1823 the duty was 42,100,000 ft. lbs.; in 1828, the duty was 76,800,000 ft. lbs.; in 1833, the duty was 84,300,000 ft. lbs., and in 1838, the duty was 90,900,000 ft. lbs., and the Holmbush engine, before mentioned, showed the duty with 30 lbs. steam cut off at 1/6, and 94 lbs. coal, to be 117, 000,000 ft. lbs.

As an example of the beneficial effects produced upon the efficiency of an individual engine, by the first application of this system of inspection, the case of the Stray Park engine may be mentioned. This engine, constructed by Boulton & Watt, had a 60 in. cylinder and when first reported in 1811, its duty amounted to 16,000,000 ft. lbs. After having been reported for three years, its duty was found to have increased to 32, 000,000 ft. lbs., this estimate having been taken from the average result of twelve months performance. Its duty was doubled in less than three years. It appears that the increase of the efficiency of these engines was not the effect of any great or sudden improvement, but was due to the combination of a number of small

improvements in the details of the operation of the engines, and to the gradual increase in the pressure of steam. These remarks, it will be admitted, apply with equal force to the inspection, reporting, and management of marine engines of the present day, and shows what economy in fuel may be effected in a similar way.

In 1840, the Cunard Company started their famous line of Mail Steamers, between Liverpool, Boston, and New York. Their first ship, the "Britannia" left Liverpool on July 4th and entered Boston harbor on the 18th, after a run of 14 days and eight hours. The "Britannia" was 1150 tons B. M., 207 ft. long, 34 ft. 4 in. beam, by 22 ft. deep; two side-lever engines; cylinders 72½ in. diameter by 6 ft. 10 in. stroke; jet condenser, D-slide valves, gridiron expansion valve on the side of the valve casing, and a cam cut-off at 3, 4, 5, and 6 tenths of the stroke; paddle wheels, 27 ft. 9 in. diam. by 8 ft. face; four flue boilers; grate surface, 222 sq. ft.; fire surface, 2698 sq. ft.; steam pressure, 12 lbs.; coal consumption, about 6 lbs. per I. H. P. per hour. The "Acadia", "Caledonia", and "Columbia", were the same as the "Britannia".

The "Hibernia", built in 1843, and the "Cambria" in 1845, were 1350 tons B. M., 220 ft. long, 35 ft. 9 in. beam, by 24½ ft. deep; two side-lever engines with cast-iron gothic framing; cylinders, 77½ in. diam. by 7


CREW
SAIL ROOM
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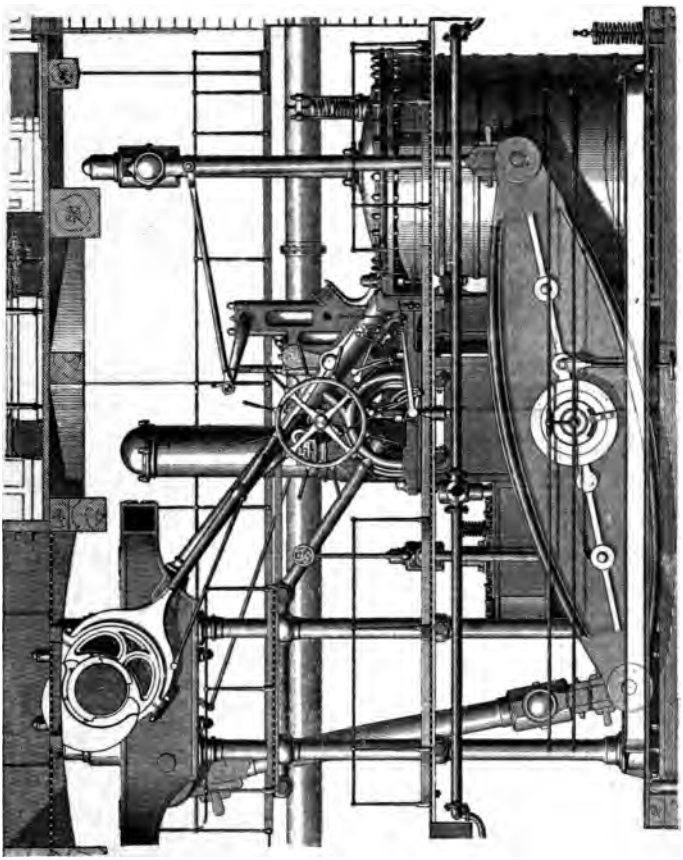
FORE CABIN
CARGO
COAL BUNKER
BOILER
PANTRY
LADIES
STATEROOMS
STEWARDS & CARGO
SALOON
WINES
GALLEY
FIDLEY
HATCH
PANTRY
SALOON
CHIEF OFFICER
WHEEL HOUSE
CAPTAIN
FORE CABIN
ENGINES
BOILERS
LADIES CABIN
STATE ROOMS
STEWARDS

"BRITANNIA."

ft. 6 in. stroke; paddle wheels, 29 ft. 9 in. diam., by 9 ft. 3 in. face; four flue boilers; grate surface, 247 sq. ft.; fire surface, 3778 sq. ft.; steam, 14 lbs.; consumption, 5½ lbs. per horse power. The "America", "Niagara", "Europa", and "Canada", built in 1848, were 1756 tons B. M., 251 ft. long, 38 ft. beam, and 25 ft. 9 in. deep; two side-lever engines, with wrought-iron framing; cylinders, 90 in. diam. by 8 ft. stroke; paddle wheels 32 ft. diam. by 9 ft. face; four flue boilers; grate surface, 314 sq. ft.; fire surface, 4926 sq. ft.; steam, 15 lbs.; consumption, 5 lbs. per horse power. The "Asia" and "Africa", built in 1850, were 2128 tons B. M., 266 ft. long, 40 ft. beam, and 27 ft. deep; two side-lever engines, wrought-iron framing; cylinders, 96½ in. diam. by 9 ft. stroke; paddle wheels, 35 ft. diam. by 9 ft. 3 in. face; four flue boilers; grate surface, 417 sq. ft.; fire surface, 7032 sq. ft.; steam 16 lbs.; consumption, 4½ lbs. per horse power; 3,000 indicated horse power.

The "Arabia", built in 1851, was 2292 tons B. M., 285 ft. long, 40 ft. 8 in. beam, and 27 ft. 6 in. deep; two side-lever engines; cylinders, 103 in. diam. by 9 ft. stroke; paddle wheels, 35 ft. 6 in diam. by 10 ft. 6 in. face; four tubular boilers; grate surface, 642 sq. ft.; fire surface, 16,948 sq. ft.; steam pressure 20 lbs.; consumption, 4 lbs. per horse power. The "Persia" was built of iron in 1855, was 3586 tons B. M., 360 ft. long,



"ARABIA'S ENGINES."

45 ft. beam, and 29 ft. 8 in. deep; two side-lever engines; cylinders, 100 in. diam. by 10 ft. stroke; eight tubular boilers; steam pressure, 20 lbs; I. H. P., 3,500. The "Scotia", the last of the side-wheel steamers for the Cunard Company, was built of iron in 1862, was 4,136 tons displacement, 379 ft. long, 47 ft. 10 in. beam and 30 ft. 6 in. deep; two side-lever engines; cylinders, 100 in. diam. by 12 ft. stroke; paddle wheels, 40 ft. diam.; eight tnbular boilers; steam pressure, 25 lbs.; I. H. P., 5,000; consumption, 160 tons coal per day; coal per indicated horse power per hour, 3.3 lbs.

The engines of these Cunard ships were designed by David Elder, and were fine specimens of side-lever marine engines built about 50 years since, were always reliable and did good service in their day. These engines and the hulls of the iron ships "Persia" aud "Scotia", were built by Robt. Napier, of Glasgow.

Owing to the greater economy in fuel of the screw propeller ships, "Russia", "Java", and others, making the same speed of 339 knots per day, and consumming 85 to 95 tons of coal per day, the "Scotia" was withdrawn and laid up in 1877. In the Summer of 1879 the "Scotia" was sold to the British Telegraph Construction and Maintenance Company, new engines and twin screws were placed in her, and she sailed from the Mersey for Singapore.

In 1850 the iron screw steamship, "City of Glasgow," the pioneer vessel of the celebrated Inman Line, sailed from Liverpool for Philadelphia on December 10th. She was 1,600 tons, and 350 horse power (nominal). The engines were two beam geared engines with jet condensers, the propeller shaft making two revolutions for one of the crank shaft, cylinders 66 ins. diameter, by 5 ft. stroke, speed 7.3 knots per hour, propeller 13½ ft. diam. by 18 ft. pitch; this ship was succeeded by the "City of Manchester," and they formed the Liverpool and Philadelphia line.

In 1857 the Inman ships went to New York, and the line was increased afterward by the "City of Philadelphia," the "City of Baltimore," and the "City of Washington."

In 1860 the "City of New York" was added, and in 1863 the "City of London," "City of Cork," and "City of Limerick" were added.

In 1868 the "City of London" and "City of Paris" were added.

In 1869 the "City of Brussels," and in 1872 the "City of Montreal."

In 1874 the "City of Chester," "City of Richmond" and "City of Berlin" came out with compound engines.

In 1876 the "City of Brussels" received new compound engines, and the trunk engines of the "City of

Montreal" were changed to compound.

In the "Brussels" the consumption was reduced from 110 to 65 tons of coal per day, and the cargo space increased by about 800 tons.

In 1882 the "City of Rome" came out. She was 586 ft. long, 52 ft. 3 ins. beam, by 37 ft. deep, tonnage 8,826 tons, draught of water 26 ft. Compound tandem engines, cylinders, three high pressure 43 in., and three low pressure 86 ins. diam., by 6 ft. stroke, three cranks, 120° apart; propeller 24 ft. diam. Eight double ended boilers, steam pressure 90 lbs., revolutions 60, speed 18 knots, I. H. P. 10,000.

The Barrow Shipbuilding Co., the builders of the "City of Rome," also built in 1883 the "Normandie," of similar design, for the French Line between Havre and New York; 450 ft. by 50 ft., by 37 ft. deep. Three tandem engines, cylinders, three 35½ ins. high pressure, and three 75 ins. low pressure, by 5 ft. 7 ins. stroke, low pressure cylinders jacketed, four double and four single ended boilers, steam 85 lbs. pressure; I. H. P. 8,000, revolutions 63 per minute, speed 17¼ knots.

The "City of Rome" was returned to the builders on account of not fulfilling the conditions of the contract. They afterwards transferred her to the Anchor Line, and that company have since run her from Liverpool and Glasgow to New York.

In 1845 the steamship "Great Britain" came out. She was built from designs of Mr. Brunel by the Great Western Steamship Co., and was 322 ft. long, 51 ft. beam, 32½ ft. deep, tonnage 3,440 tons, draught 16 ft. There were four engines, cylinders 88 in. diam., by 6 ft. stroke, drum on the crank shaft 18 ft. diam., propeller shaft drum 6 ft. diam., and they were connected by four chain bands, the propeller shaft making three revolutions for one of the crank shaft. The propeller had six blades, diam. 15½ ft., pitch 25 ft., speed 12 knots.

In September, 1846, the "Great Britain" went ashore in Dundrum Bay on the Irish coast. She was floated again in August, 1847, was taken to Liverpool, where she was repaired, and fitted with two geared oscillating engines by Penn, and a three bladed screw. The vessel was employed in the transport service during the Crimean war, and afterwards ran from Liverpool to Australia as a passenger and freight ship for many years.

In 1882 the "Great Britain" was altered to a full rigged sailing vessel.

In 1886 she put in to the Falkland Islands leaking, was condemned, and remains there still as a coal hulk (1893).

In 1854 John Elder took out a patent for compound

engines, having two pairs of high and low pressure cylinders, each pair being side by side. and placed in an inclined position ; one pair of high and low forward, and the other pair abaft the surface condenser, which lies athwart ship, directly under the crank shaft. The centre lines of the two pairs of cylinders inclose between them an angle of about 60°. The connecting rods of the two high-pressure cylinders are connected to one crank, and the two low-pressure to the other, the two cranks being placed diametrically opposite. It follows from this arrangement that the steam passes direct from the top or bottom of one of the high pressure cylinders, to the corresponding end of the adjacent low pressure cylinder, the length of the connecting passages being thus rendered as short as possible. The cylinders are steam jacketed both at the sides and bottoms. The small cylinder has triple ports, and the steam is admitted by a pair of gridiron valves fixed on a single spindle, and kept up to their seats by springs at the back. The low pressure cylinders have double steam ports, and the distribution of the steam to these cylinders is effected by a pair of slide valves working in separate chambers. The two valves are fixed on one spindle, which works through a bush placed in an opening in the partition dividing the two chambers. The surface condenser is placed directly beneath the crank

shaft. and it in fact forms a kind of base plate, to which the cylinders are fixed. The condenser is arranged so that the condensing water passes through the tubes, it being made to traverse their length three

"JOHN ELDER."

times. The two circulating pumps are placed at one end, and the two air pumps at the other end of the condenser, each being driven by an independent eccen-

tric. The paddle wheels are of the feathering class, and are fitted with wrought iron floats, the edges being so sharp that they offer little resistance in entering and leaving the water.

The Pacific Steam Navigation Company about 1859 fitted a set of these engines on board each of their steamers "Lima" and "Bogota," instead of the old side-lever engines, which had two cylinders 73 in. diam. by 6 ft. stroke, and four tubular boilers with 260 ft. of grate surface, and 7,000 ft. of fire surface, steam pressure 16 lbs., coal consumption 3,700 lbs. an hour, speed about 10½ knots per hour, ships 250 ft. long by 30 feet beam.

The new compound engines were two pairs, cylinders 52 in. and 90 inch by 5 ft. stroke, and two tubular boilers with 130 ft. grate surface, and 3,200 ft. of fire surface, steam pressure 26 lbs., coal consumption 2,200 lbs. an hour, I. H. P. 1160, or 1.9 lbs. per I. H. P. per hour.

The machinery space was 30 ft. shorter, the boiler power is about half what it was before, the speed of the ship was increased, and the consumption about one-half what it formerly was. The accommodation was much increased, the weight of the hull was increased by adding a spar deck, etc., to the extent of 150 tons, and the coal endurance was increased from

8 to 11 days consumption. The steamers "Callao" and "Valparaiso," belonging to the same company, were fitted with similar machinery.

In 1860 the steamers "San Carlos" and "Guayaquil" were built by W. Simons & Co. on the Clyde for the Pacific Steam Navigation Company; engines by Randolph, Elder & Co.; ships 210 ft. long by 30 ft. beam, by 18 feet deep, fitted with double cylinder engines, geared, cylinders two 53 in. and two 31 in. diam., by 2 ft. 11 in. stroke, steam jacketed, revolutions of engines 48 per minute, of screw 96 per m., Griffith's screw diam. 10 ft. 6 in., pitch 13 ft. 4 in.; one spiral flue boiler 12 ft. 6 in. diam., by 24 ft. high, grate surface 74 ft., fine surface 2,200 sq. ft.; steam pressure 50 lbs, coal per hour 1,120 lbs.. I. H. P. 531, coal per horse-power per hour 2.1 tbs., speed of ship 11½ knots. The success of these ships, and their great economy in coal consumption, while running on the Pacific coast, soon became widely known.

In June 1860 the steamship "Great Eastern" arrived in New York on her first voyage from Southampton. She was designed by Brunel, built by J. Scott Russel in London, and was 680 feet long, 82 ft. beam, 58 ft. deep, tonnage 24,320 tons, draught loaded 30 ft., built with double bottom and longitudinal frames, and iron deck planked above.

This vessel had both paddle wheels and screw. The paddle wheel engines, built by J. Scott Russel, were on the diagonal oscillating plan, four cylinders, each 74 in. diam. by 14 ft. stroke, with jet condenser, paddle wheels, 60 ft. diam., by 13 ft. face, revolutions 10 per minute. The screw engines, built by Boulton & Watt, were horizontal direct acting, four cylinders 84 in. diam. by 4 ft. stroke, revolutions 34 per minute. Propeller had four blades, diam. 24 ft., pitch 37 ft. There were four horizontal tubular boilers for the paddle engines, and six for the screw engines, steam pressure 25 lbs., I. H. P. 8,000, speed 14 knots, coal per day 250 tons.

This vessel did good service while laying the second Atlantic cable, but was not a commercial success, and was subsequently sold for £16,000, and broken up at New Ferry on the Mersey in 1890.

In 1859 the British Association, at the meeting held in Aberdeen, appointed a committee to report on steamship performance the following year.

In 1860 at the meeting of the association in Oxford the committee made a lengthy report with tabulated accounts, showing the results of their inquiry, and which was published in the Londen Artizan for July, 1860.

The following are some of the results reported. Pacific S. Navigation Co.'s steamers "Lima," "Bogota,"

"Callao" and "Valparaiso," steam pressure 26 lbs., coal per horsepower per hour 1.9 lbs. Steamers "San Carlos" and "Guayaquill." steam pressure 50 lbs, coal per horsepower per hour 2.1 lbs. The U. S. S. "Wyoming," steam pressure 30 lbs., coal per horsepower per hour 4 lbs. The U. S. S. "Niagara," steam 11 lbs coal 4½lbs.; the U. S. S. "Massachusetts," steam 32 lbs., coal 4½ lbs. The French "Messageries Imperiales" (merchant steamers), steam pressure 10 lbs., coal per horse power per hour 8 lbs. The Holyhead and Kingston mail packets, steam 14 lbs., coal per horsepower per hour 6½ lbs. The West India mail steamers "Atrato" and "La Plata, steam 14 lbs., coal per horsepower per hour 7 lbs.

On the British naval ships the average steam pressure was 20 pounds., consumption of coal not reported, but it was probably about 7 lbs. per horsepower per hour. It seems singular that no attention had been given before this time to the question of coal economy on steamships, by the British Admiralty.

The committee on steamship performance was reappointed in 1860 and again in 1861. At this date the Pacific Steam Navigation Co. had almost single handed shown the way to encourage the adoption of really practical and economical plans, but after attention had been so strongly called to the subject by the British

Association committees, the British Admiralty and steamship owners began to investigate the subject for themselves. As a result in 1860 the Admiralty ordered three sister frigates to be built in the dock yards, and contracted with three firms for competitive machinery for them, offering a premium of £2,000 to the builders whose engines propelled their ship under similar circumstances with the greatest speed, or the greatest distance with the least fuel.

The "Constance" was fitted by Randolph, Elder & Co., with compound engines, having two high-pressure cylinders, 60 in. diam., and four low-pressure cylinders 78 in. diam., by 45 in. stroke. The shaft had three cranks, the two high-pressure cylinders were connected to the middle crank, and two of the low-pressure cylinders to each of the end cranks. The cylinders were steam jacketed, and Sewell's surface condenser was used.

The "Octavia" was fitted by Mandslay & Co., with three horizontal engines connected to three cranks 120° apart; cylinders steam jacketed and each 66 in. diam by 42 in. stroke, Hall's surface condenser.

The "Arethusa" was fitted by Penn & Son, with two horizontal trunk engines, connected on two cranks at right angles. cylinders equal to 80 in. diam. by 42 in. stroke, and Spencer's surface condenser.

After long delay, the trials came off during the Summer of 1865. The ships all left Plymouth at the same time, each coaled to the same amount. After the start the "Constance" and "Arethusa" steamed together for three days, the "Octavia" not in sight. A gale, however, separated them. In due time the "Constance" steamed into Maderia. On the third day after her arrival the "Octavia" made her appearance under canvass, and coal all consumed. The "Arethusa" did not arrive until the fifth day after the "Constance," also under canvas, coal being all done. It turned out that while the "Constance" consumed about 45 tons per day, the other ships consumed from 65 to 90 tons in the same time.

The superior economy of the double-cylinder engine was, by these extraordinary results, placed beyond question, and the least that could be said about it was that Randolph, Elder & Co., were well entitled to the premium they so strenuously endeavored to win, and had moreover so gallantly won.

About 1869 the British Admiralty ordered two corvettes, the "Tenedos" and "Briton," of about 1,600 tons each, to be fitted with compound engines. The "Tenedos" was fitted by John Elder & Co., with back-acting compound engines, cylinders 57 ins. and 90 ins. diam. by 30 ins. stroke, connected to cranks at right angles, with

counterbalance weights on cranks, surface condenser, six cylindrical boilers, with two cylindrical furnaces in each, steam pressure 60 lbs., cylinders, bottoms, heads, and pistons steam jacketed, slide valve on low-pressure cylinder, and slide valve with a cut-off valve on the back, on the high-pressure cylinder. At the six-hours steam trials in 1870, the consumption was 1.58 lbs. coal per horse-power per hour for 8 knots, and 443 I. H. P.

It was 1.35 lbs. for 10 knots, and 867 I. H. P., and it was 2.32 lbs. for 13 knots, and 2018 I. H. P.

The "Briton" was fitted by J. & G. Rennie with compound engines, cylinders 57 ins. and 100 ins. diam. by 33 ins. stroke, connected to cranks at right angles, surface condenser, receiver between the cylinders with E. A. Cowper's arrangement for re-heating the steam, steam pressure 60 lbs.

At the six-hour steam trials in 1870, the consumption was 1,675 lbs. coal for 8 knots, and 597 I. H. P.

It was 1.515 lbs. coal for 10 knots and 1100 I. H. P. and it was 1.98 lbs. coal for 12.76 knots, and 2019 I. H. P.

These trials were considered highly satisfactory by the Inspectors for the Admiralty.

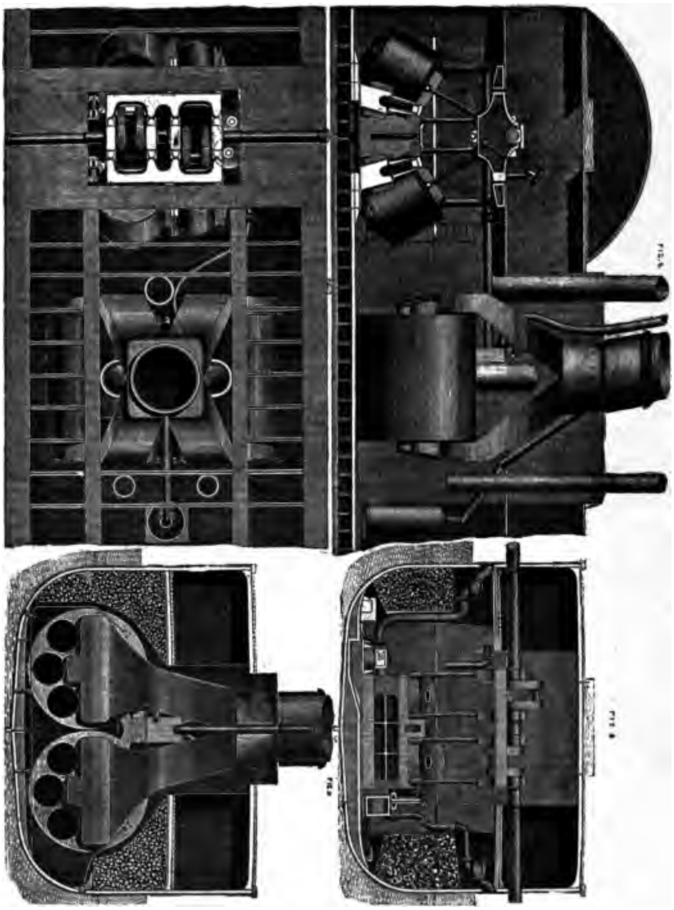
In 1868–9 John Elder & Co. built the "Italy" for the National Line; 400 ft. long, 42 ft. beam, and 36 ft.

deep, with compound engines, cylinders 60 and 96 in. diam. by 4 ft. stroke, steam jacketed, cranks at right angles, surface condensers, 3 cylindrical double ended boilers, with six cylindrical furnaces in each, and three superheaters, steam pressure about 60 lbs. coal consumption about 2 lbs. P. I. H. P. per hour.

This ship proved very successful, and many similar ships have since been built. John Elder died about the time this ship was completed, and it may be considered one of his last and best efforts.

In 1869 John Elder & Co. built the "Sin Nanzing" for the North China Steam Navigation Co. She was 225 ft. long, 32 ft. beam, and 23 ft. deep, with compound diagonal engines, two high pressure cylinders, 38 in. diam. and two low pressure cylinders, 76 in. diam. by 4 ft. 3 in stroke, surface condenser, two cylindrical double ended boilers, with six cylindrical furnaces in each, steam drum on each boiler, paddle wheels 19 ft. 6 in. diam. by 7 ft. 6 in. face, steam pressure 55 lbs., both cylinders steam-jacketed, consumption of coal 2 lbs. per I. H. P. per hour.

In this year, 1869, after John Elder's patent of 1854 had expired, W. Simons & Co., of Renfew on the Clyde, built the "India" for the Anchor Line, 311 ft. long, 36 ft. beam, and 23½ ft. deep, 2200 tons, with compound engines, vertical, two pairs of cylinders 36 in. and 72 in.



"SIN NANZING'S ENGINES."

diam. by 3 ft. stroke, each high pressure cylinder connected to a crank opposite the one to which the low pressure cylinder is connected, and one pair of cranks was at right angles to the other, cylinders steam jacketed, cut-off valve on the back of valve on the H. P. cylinder. Two cylindrical boilers, double ended, with six furnaces in each, steam pressure 40 lbs. Propeller, four bladed, 16 ft. diam. by 22 ft. pitch, surface condenser, consumption 36 tons coal per day, average speed 11½ knots. The performance of this ship was considered highly satisfactory.

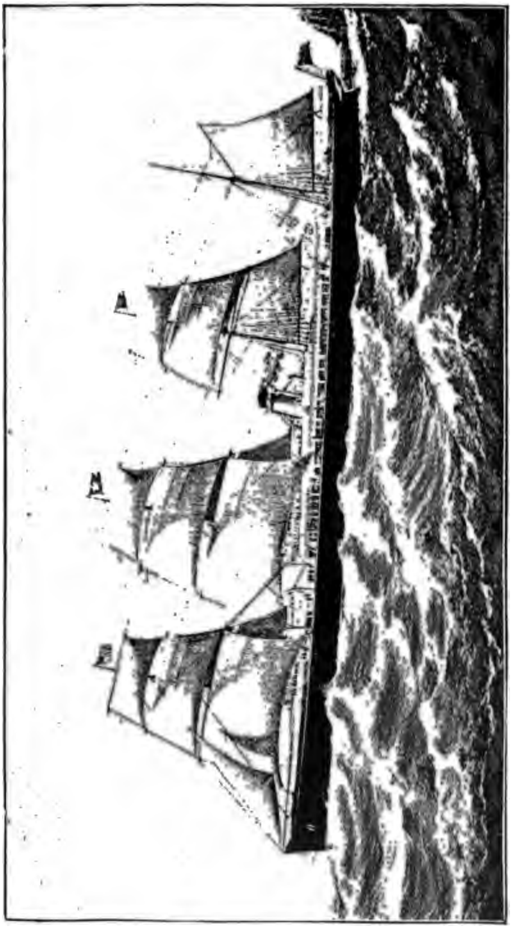
During the decade from 1860 to 1870, before the surface condenser had been perfected, and before the introduction of high pressure steam in marine boilers, many varieties of tubular superheaters in the uptake were introduced on ships of war, both in Europe and the U. S., and a considerable saving of coal was effected. Bourne estimates the average saving at that time from superheaters was about 10 per cent.

But on merchant steamers, steam chimneys or steam chests were generally used for drying the steam, and separating it by the action of gravity from the water held in suspension. A good example of this practice was introduced by David Elder (who was called the father of Clyde engineers) on the earlier Cunard steamships, which commenced to run in 1840. A short

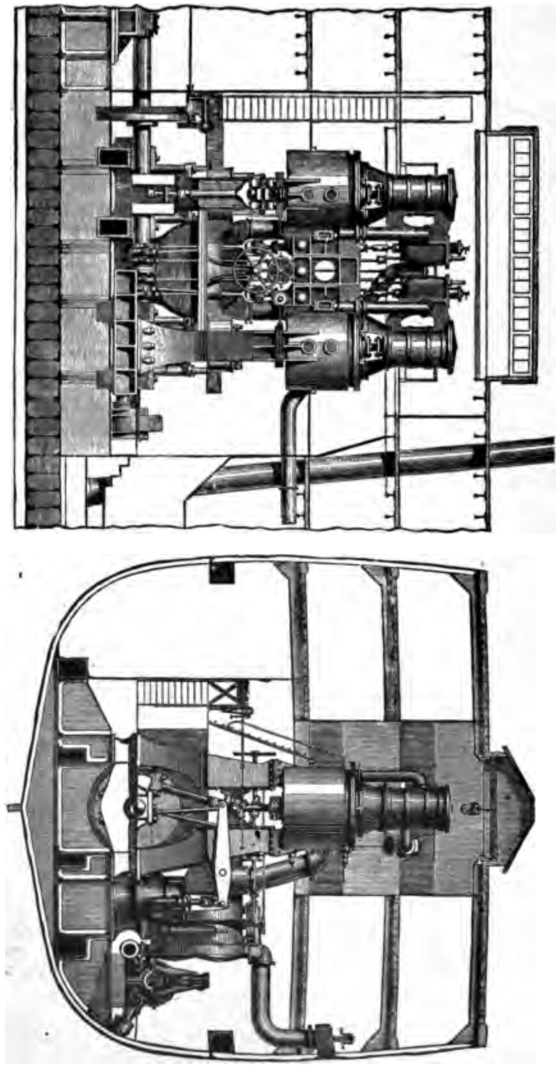
chimney projected about 4 ft. above each boiler, and the four boilers were connected by a steam chest or chimney about 8 ft. high, placed above them, each boiler was connected to this chest by a stop-valve pipe, which delivered the steam into the chest, and the steam pipes to the engines were connected to the top part of this steam chest. The boilers were of the flue type, with large roomy furnaces and good facilities for cleaning them. The engines were on the side-lever plan, D-slide valve, gridiron cut-off valve placed on the side of the valve casing, worked by cams on the paddle shaft, and cut off the steam at .3, .4, .5 and .6 of the stroke, the main valve cut-off at .7, steam pressure about 12 lbs., the cut-off was put on and shortened toward the end of the voyage, as the ship lightened up by the consnmption of coal.

About 1870 the surface condenser had been substantially perfected by Hall, Spencer, Sewell, and Lighthall, and as fresh water could be furnished to the boilers, people began fo use higher pressures on the boilers of sea going steamers-

In March 1871 the "Oceanic", the pioneer vessel of the While Star Line, arrived in New York: the hull was of iron, and constructed by Harlan & Wolff, of Belfast, length 432 ft., beam 41 ft., depth 36 ft., draught of water 24 ft., tonnage gross 4350 tons.



"S. S. OCEANIC."



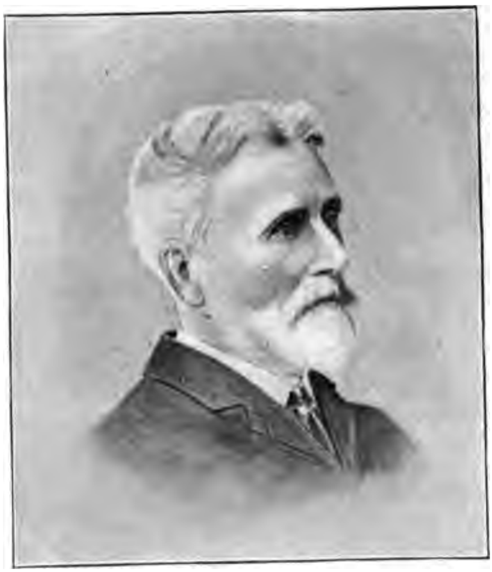
"S. S. OCEANIC'S ENGINES."

The engines were built by Maudslay, Son & Field, of London. They were on the tandem compound principle, with two cranks at right angles and counterbalanced, cylinders were two 41″ and two 78″ in diam. by 5 ft. stroke, slide valves, with cut-off valves on high-pressure cylinders, surface condenser, steam jackets, and super-heater in the chimney, propeller 23 ft. diam. by 31 ft. pitch, revolutions 51 per minute. Ten two-furnace oval boilers, grate surface 411 sq. ft., heating surface 12,060 sq, ft., steam pressure 65 lbs., indicated horse power 3,509, consumption of coal 65 tons per day, coal per I. H. P. per hour 1.75 lbs., average speed 14¼ knots, max. 16. The steamers "Adriatic", "Atlantic", "Baltic", "Republic", "Celtic", "Britannic", and "Germanic", succeeded the "Oceanic", and were somewhat larger, but of similar design.

In 1874, the steamship "Propontis", belonging to W. H. Dixon, of Liverpool, was fitted with new machinery by John Elder & Co. The engines were designed by A. C. Kirk, and were on the triple-expansion principle, with three cylinders 23″, 41″ and 62 in. diam. by 3 ft. 6 in. stroke, three cranks 120° apart, cylinders steam jacketed on both sides and ends. The boilers were Rowan & Horton's patent water-tube type of boiler to carry 150 lbs. pressure, coal consumption from 1.6 to 1.8 lbs. per I. H. P. per hour. These engines worked well,

but the boilers gave trouble and were taken out, and new boilers of the ordinary type to carry 90 lbs. pressure were substituted, in 1876.

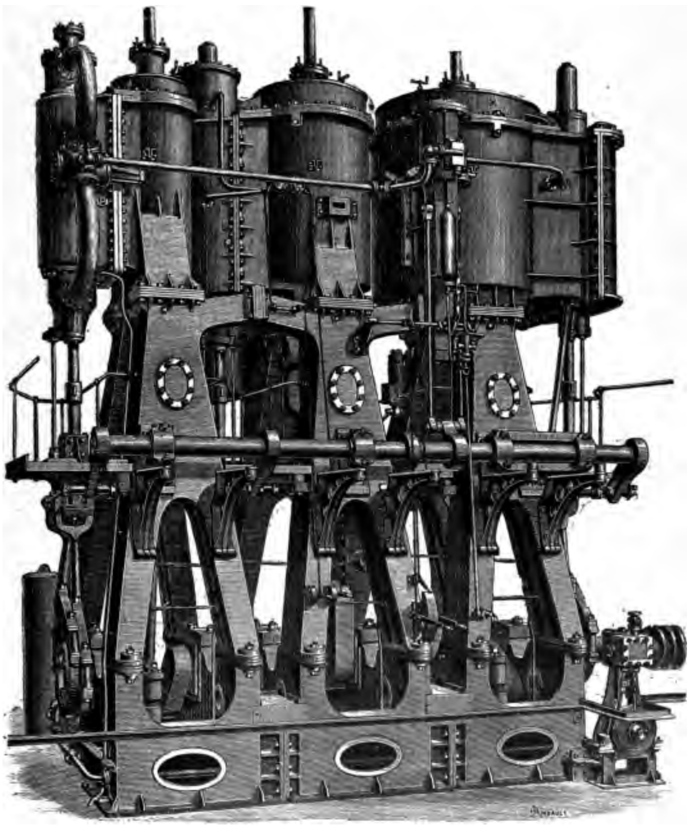
In 1881 R. Napier & Co. built the steamship "Aberdeen" for Geo. Thompson & Co., for their trade from



A. C. Kirk.

England to Australia and China. The design was by A, C. Kirk, the managing partner. The ship was 350 ft. long, 44 ft. beam, and 33 ft. deep. The engines

were similar to those on the "Propontis", cylinders 30 in., 45 in., and 70" in. diam. by 4 ft. 6 in. stroke. ·The



"S. S. ABERDEEN'S ENGINES."

boilers two in number are ordinary double-ended ones, constructed of steel, with six of Fox's corrugated furnaces in each, steam pressure 125 lbs., high-pressure cylinder not jacketed, second cylinder jacketed with steam of 50 lbs. pressure, and the low-pressure cylinder with steam of 15 lbs. above the atmosphere. At 1,800 I. H. P. the consumption of coal was 1.28 lbs. per I. H. P. And at 2,631 I. H. P. and at a speed of 13.74 knots the coal consumption was 1.5 to 1.6 lbs. per I. H. P. per hour.

About this time Samson Fox's corrugated furnaces came into use, which made it possible to carry steam of much higher pressure, and so to secure more economy of fuel by expanding the steam to a greater degree.

About 1878–9 another type of engines came into use, and were fitted on the steamship "Gallia", built by J. &. G. Thomson for the Cunard line. This ship was 450 ft. long, 44 ft. beam, and 36 ft. deep. The engines had three cylinders, and three cranks 120° apart, high-pressure cylinder 60 in. diam. and two low-pressure cylinders 80 in. diam. by 5 ft. stroke, steam jacketed, surface condenser, steam pressure 75 lbs., eight cylindrical tubular boilers, with three furnaces in each, coal per day 98 tons, I. H. P. 5,300, coal per I. H. P. 1.73 lbs., speed 16 knots.

In 1879 the celebrated steamer "Arizona," of the

Guion Line, went on her route from Liverpool to New York, and was said to have marked a new era in the type of Atlantic mail steamers. After running successfully for a time, she struck an iceberg off the coast of Newfoundland, while steaming at fourteen knots an hour at night. The bow was crushed in for a length of 26 feet, but the collision bulkhead saved her. After temporary repairs at St. John she crossed the ocean to Liverpool, and afterwards went to Glasgow for repairs. Since then she has been running successfully. This ship is 465 ft. long, 45½ ft. beam, and 37½ ft. deep; gross tonnage, 5,146 tons. Engines three cylinder compound, high pressure cylinder 62 in. diam., two low pressure cylinders each 90 in. diam., by 5 ft. 6 in. stroke, cast iron cylinder liners, steam-jacketed all over, piston-valves, six double-ended boilers, and one single-ended, 39 furnaces in all, steam pressure 90 lbs., indicated H. P. 6,300; speed, 390 knots per day; consumption about 1.75 lbs.

The "Alaska," of the Guion Line, came out in 1882. Engines 68″, 100″, 100″, by 6 ft. stroke; I. H. P., 10,000; speed, 420 knots per day. In 1884 the "Oregon" came out, and was purchased by the Cunard Co. and made several successful voyages before she was lost by collision off the Long Island coast. She was 500 ft. long, 54 ft. beam and 38 ft. deep; tonnage, 7,375 tons; en-

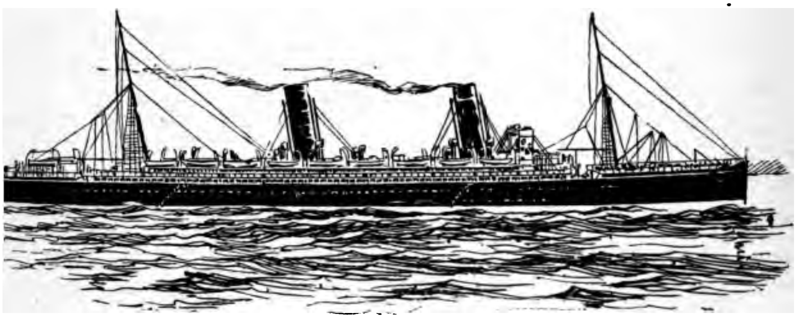
gines 70″, 104″, and 104 in. diam. by 6 ft. stroke; I. H. P. 13,,300. Many ships were fitted with engines of this type, including the Cunard Co.'s steamer. "Servia," built by Thomson, which came out in 1882; she was 530 ft. long, 52 ft. beam and 40 ft. 9 in. deep; engines 72″, 100″ and 100″ diam. by 6 ft. 6 in. stroke. Six double-ended boilers and one single, 39 furnaces in all; steam 90 lbs., I. H. P. 10,300; consumption 190 tons coal per day, per indicated H. P. 1.7 lbs.

The "Aurania," built by Thompson, came out in 1883; was 470 ft. long, 57 ft. beam and 38½ ft. deep; engines 68″, 91″, and 91″ diam. by 6 ft. stroke, I. H. P. 8,500.

The "Umbria" and "Etruria", built by John Elder & Co., in 1884, gross tonnage 8,000 tons, 520 ft. long, 57 ft. beam, 40 ft. deep, engines 71″, 105″, and 105″ diam. by 6 ft. stroke, I. H. P. 13,300, speed 20 knots per hour, nine boilers, 72 furnaces, steam pressure 110 lbs., consumption 310 tons coal a day, per I. H. P. 2 lbs.

The "Campania" and "Lucania," built by the John Elder or Fairfield Co., Glasgow, for the Cunard Line, are 600 ft. long on the water line, 620 ft. over all by 65 ft. 3 inches beam, and 43 feet in depth; gross tonnage about 12,500 tons. They have twin screws, driven by two sets of triple ex-

pansion engines ; each set has five cylinders and three cranks 120° apart; the two high-pressure cylinders are 37 ins, diameter, the intermediate 87 inches, and the two low-pressure 98 ins, diameter, by 5 ft. 9 ins. stroke; the in-



"S. S. CAMPANIA."

termediate cylinder connects to the middle crank, and one high and one low, arranged tandem, connects to each end crank.

Steam will be supplied by 12 double-ended boilers, with 8 furnaces in each, and one single-ended auxiliary boiler. Steam pressure about 160 pounds ; indicated horse-power, maximum 30,000 H, P.

The Campania left Liverpool for New York on her first voyage on April 22nd, 1893, and New York on May 6th, 1893.

The "Parisian", built by R. Napier & Son for the

Montreal Steam Shipping Company, came out in 1881, was 450 ft. long, 46 ft. beam, and 36 ft. deep, gross tonnage 5,500 tons, engines 60″, 85″, and 85″ diam. by 5 ft. stroke, four double-ended boilers, with six furnaces in each, steam pressure 75 lbs. speed 14½ knots, I. H. P. 5,000.

In 1884 R. Napier & Co. built the steamship "Australasian", for Geo. Thompson & Co. She was 350 ft. long, 44 ft. beam, and 33 ft. deep, similar to the "Aberdeen"; engines triple expansion, cylinders 32″, 46″, and 70″ diam. by 4 ft. 6 ins. stroke, with some changes in the valve gear. In other respects this ship was a duplicate of the "Aberdeen", and it was the success of tne Aberdeen on the long Australian voyage that showed ship owners the economical advantages to be attained by triple expansion, and which induced the owners to build the Australasian. Coal consumption on trial trip was 1.28 lbs, per I. H. P. and during the voyage including coal used for all purposes on board from 1.5 to 1.6 lbs. per I. H. P.

After building the "Aberdeen" R. Napier & Co. supplied to the Mexican Transatlantic Co. three steamers, each fitted with engines of 5000 indicated horsepower of the same type as those of the "Aberdeen", with three cylinders and three cranks.

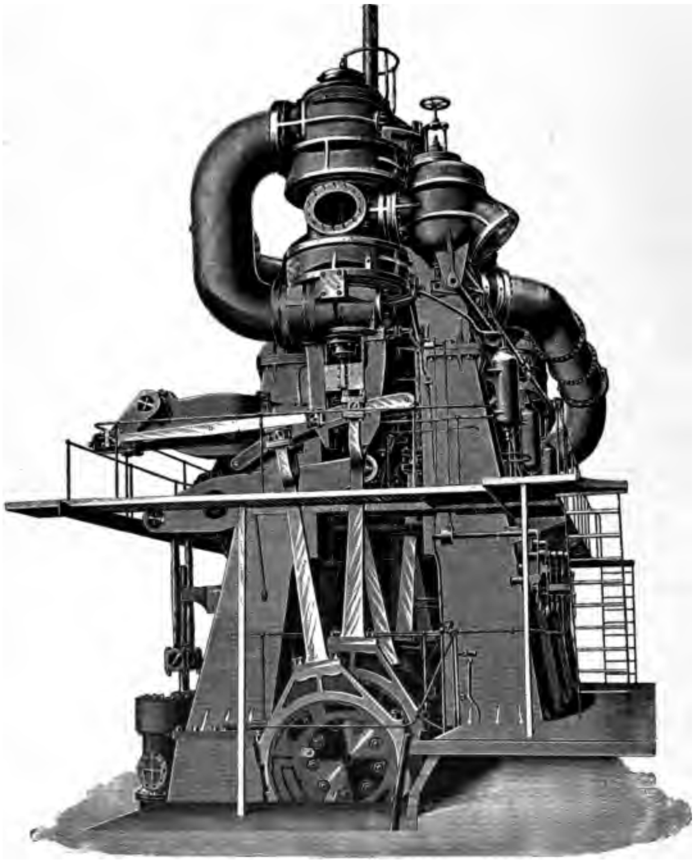
About 1886, the three New York and Bremen

steamships "Aller", "Trave", and "Salle" built by John Elder & Co., came out, length 438 ft., beam 48 ft., depth 36 ft., 3 ins., 5500 tons burden, 4 masts, indicated horse-power 7,974, Triple expansion engines, cylinders 44 ins., 70 ins. and 100 ins. diam., by 6 ft. stroke. Steam pressure, 150 lbs.

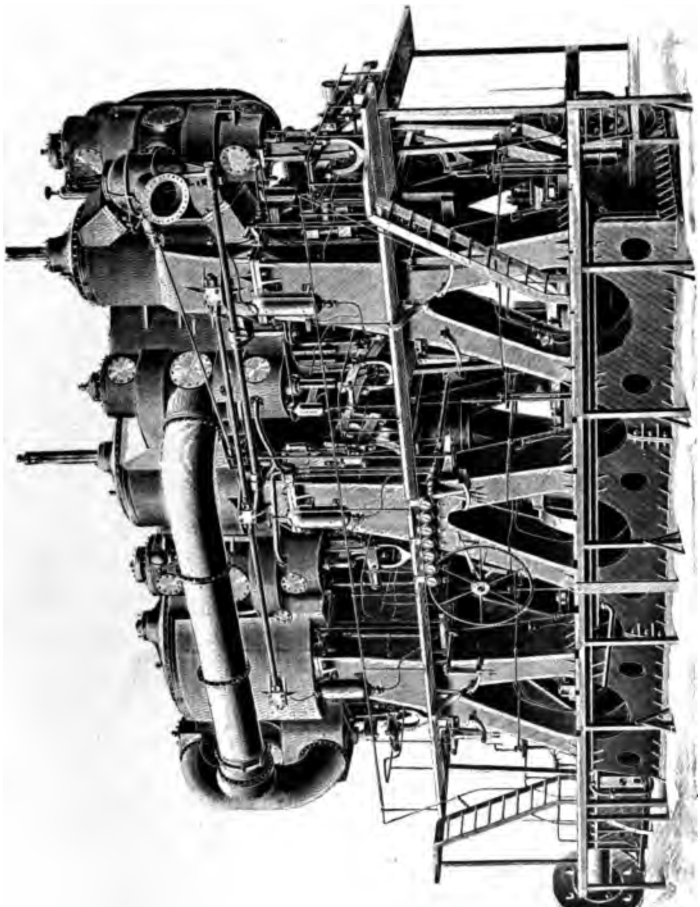
Another example of the triple expansion engine was fitted on the Bremen steamship "Lahn", built by John Elder & Co., came out in 1888, length 448½ ft., beam 49 ft., depth 36½ ft., indicated horse-power 9,500, two cylinders, 32½ in., one 68 in. and two 85 in. diam., by 6 ft. stroke, steam pressure, 150 lbs, the high pressure cylinders were tandem to (or above) the low pressure, which were connected to the end cranks, and the intermediate cylinder connected to the middle crank. The builders claimed that this arrangement gave an equal distribution of the power on the three cranks, speed, 18.75 knots an hour, the coal consumption on this ship at sea averages about 1.5 lbs. coal per indicated horse-power per hour.

Some examples of the modern twin screw steamers are as follows:

The "City of New York" and "City of Paris", came out in 1888 and 1889, and were built by J. & G. Thomson, of Glasgow, length 525 ft., beam 63¼ ft., depth 42 ft., tonnage 10,500 tons, twin screws, two sets of



"ENGINES, S. S. PARIS."



"ENGINES, S. S. PARIS,"

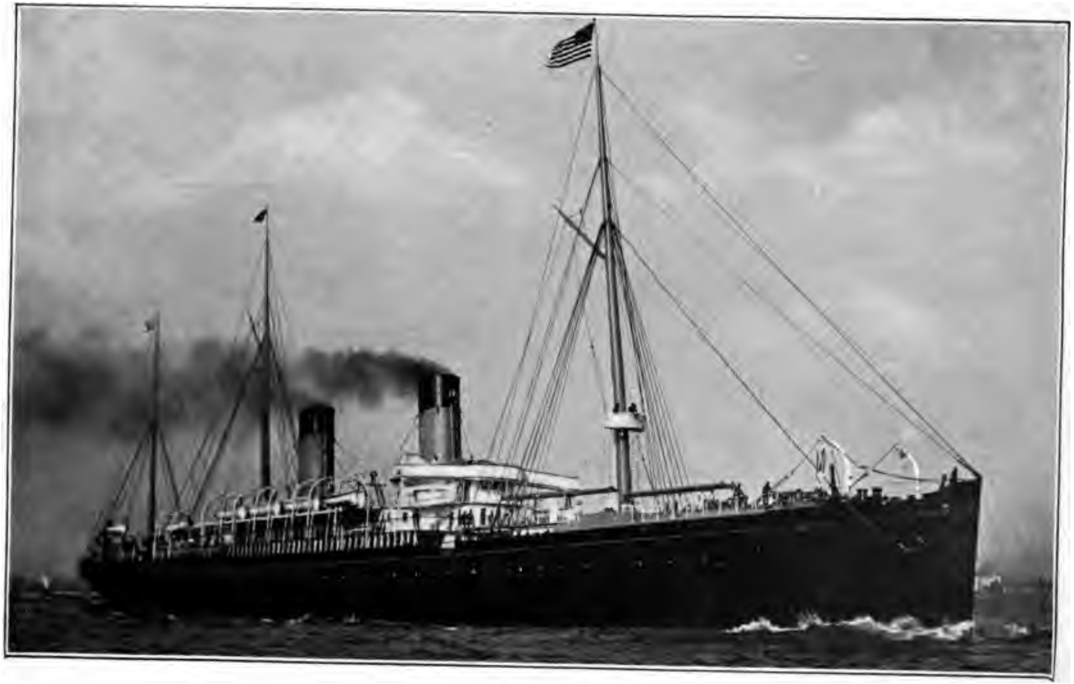
tripple expansion engines, with steam jackets, cylinders (in each set) 45 in. 71 in. and 113 in. diam., by 5 ft. stroke; all the valves are piston valves, one on the high, two on the intermediate, and four on the low-pressure cylinders, nine double ended boilers, with six furnaces in each, grate surface 1,270 sq. ft., fire surface 50,040 sq. ft., steam press, 150 lbs., closed fireroom, with forced draught, average speed per hour 20 knots, consumption of coal per day, 328 tons, indicated horse-power, 18,000, coal per indicated horse-power per hour, 1.7 lbs.

The machinery of the "City of Paris" broke down in 1890, and while it was being repaired the Howden system of hot-blast was fitted to the boilers.

In consequence of an act of Congress of July, 1892, providing for the transfer of the "New York" and "Paris" to the American flag, on condition that double the foreign built tonnage admitted to American register must be built by the owner or owners of such foreign built ships in American ship yards.

The contract for the construction of two swift steamers for the new American Line to Southampton was signed on Feb. 7th, 1893, with Cramp & Sons, of Philadelphia.

It is intended that these vessels will have twin screws, and direct acting quadruple expansion engines,



S. S. "Majestic"

with a working pressure of 210 lbs of steam, supplied by the ordinary type of Scotch boilers of moderate diameter.

The American flag was formally raised upon the "NewYork" at New York, on Feb. 22nd, 1893, and she sailed for Southampton on Feb. 25th, 1893, under the American flag.

The White Star steamers "Teutonic" and "Majestic" came out in 1889 and 1890 and were built by Harland & Wolff, of Belfast, length 582 ft., beam 57½ ft., depth 39 ft. 4 in., tonnage 9,686 tons, twin screws, two sets of triple expansion engines, cylinders (in each set) 43 in., 68 in., and 110 in. diam. by 5 ft. stroke, twelve double ended boilers, with six furnaces in each, grate surface 1,154 sq. ft., fire surface 40,972 sq. ft. steam pressure 180 lbs.

Howdens hot-blast, average speed per hour, 20 knots, consumption of coal per day 316 tons, indicated horse-power 1,800 coal per indicated horse-power her hour 1.6 lbs.

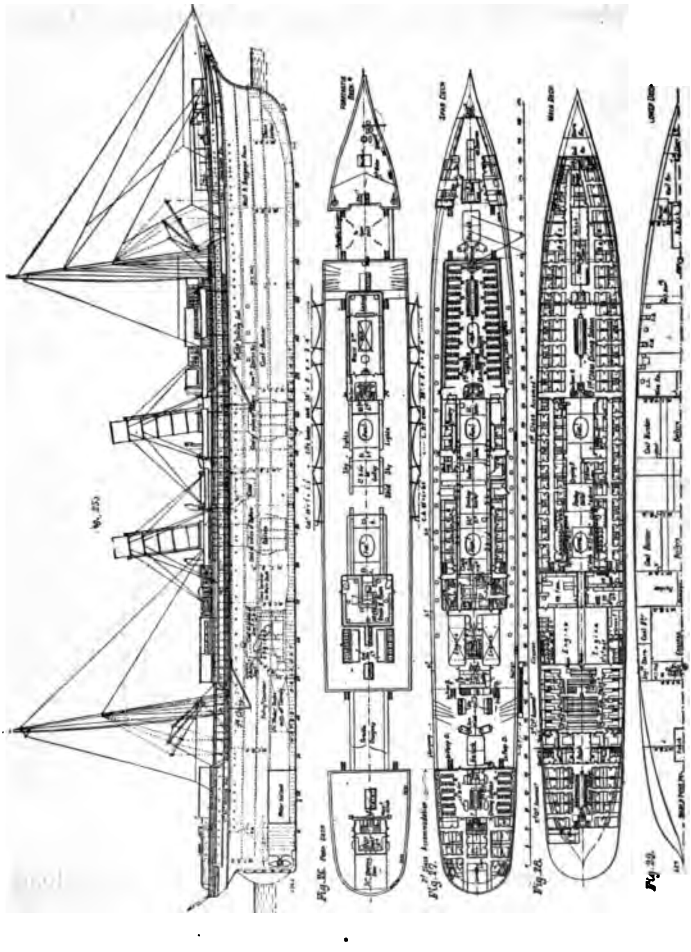
The twin screw steamers of the Hamburg and New York Line, came out in 1889 and 1890. The "Columbia", built by Lairp, Birkenhead, is 460 ft. long, 56 ft. beam, by 38 ft. deep, two sets of triple expansion engines, cylinders 41 in., 66 in. and 101 in. diam., by 5½ ft. stroke. Nine double ended boilers, with six fur-

naces in each, steam pressure 160 lbs. I. H. P., 12,500, speed 18½ knots an hour.

The "Augusta Victoria" and the "Fuerst Bismark", of the Hamburg and New York Line, were built at Stetin, Prussia, and are of similar dimensions and design to the "Columbia". Speed about 18½ knots.

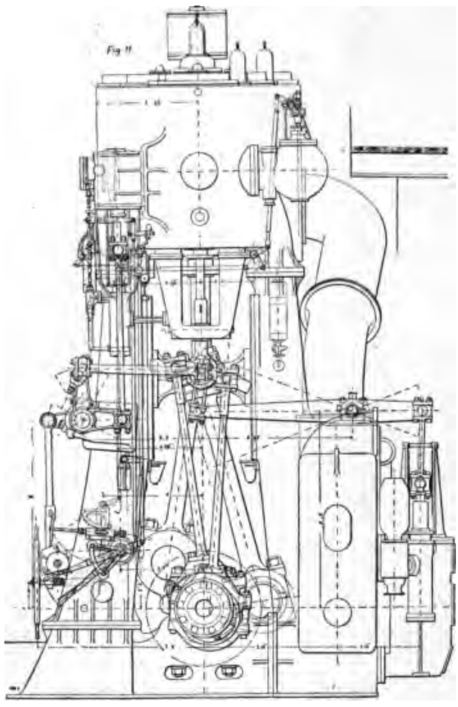
The steamsip "Normannia", also of the Hamburg Line, was built by the Fairfield (Elder) Co., Glasgow, and is 520 ft. long, 500 ft. between perpendiculars, 57½ ft. beam, and 38 ft. deep, gross tonnage 8,500, twin screws, two sets triple expansion engines, cylinders 40 in., 67 in., and 106 in. diam., by 5½ ft. stroke, piston valves. on each cylinder. Nine double ended boilers, with eight corrugated furnaces in each, making 72 in all, steam pressure 160 lbs. Independent air, feed, and bilge pumps in each engine room. In the engine rooms are also fitted auxiliary condensers. Wier's feed-heaters and evaporators, and other modern appliances for economising fuel and labor. Each fireroom is fitted with two fans and engines to supply air to the furnaces under all atmospheric conditions, average sqeed 19¼ knots, consumption about 1.6 lbs. coal per horse-power per hour.

The twin-screw steamer "Scott", belonging to the South African Mail Co., from England to Cape Colony,



"S. S. Scott."

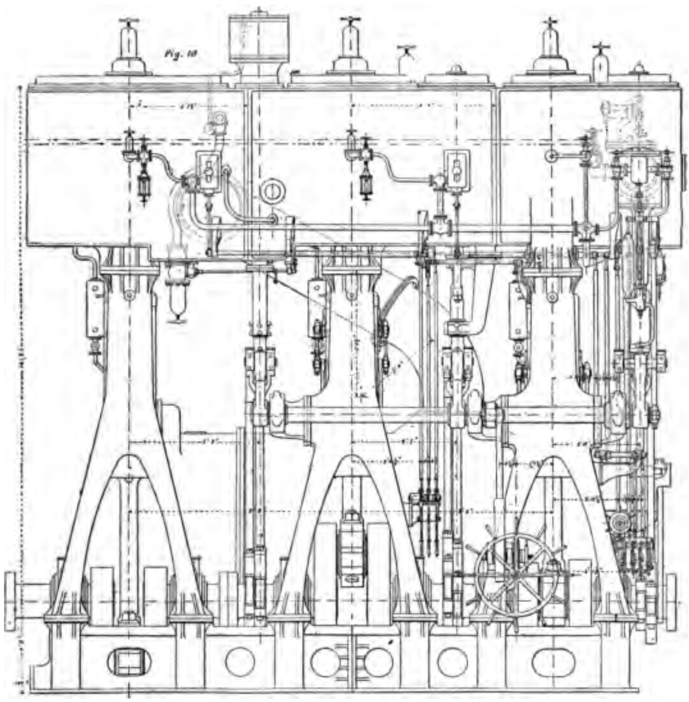
built by Denny & Co., Dunbarton, is one of the latest examples of that type, and went on her route in 1891.



"S. S. Scott's Engines.

This ship is 500 ft. long over all, and 460 ft. on the load water line, 54½ ft. beam, and 37½ ft. deep, tonnage,

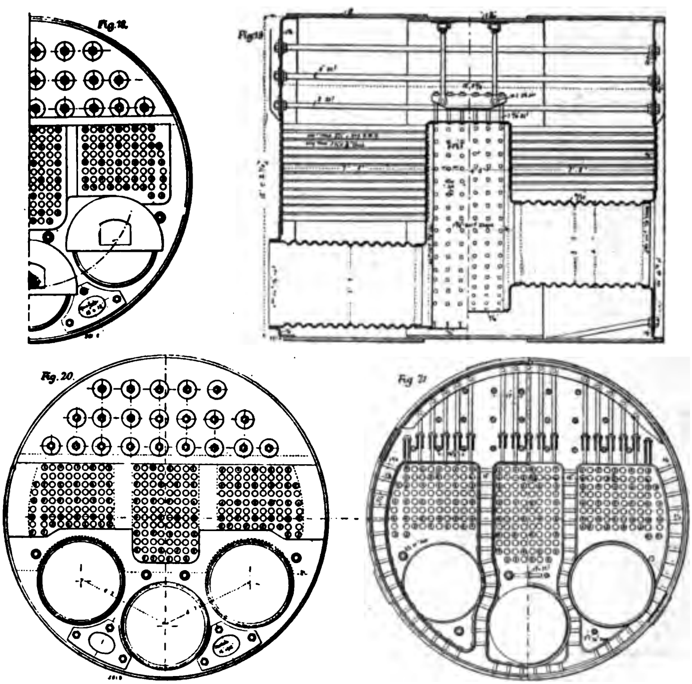
6,884 tons, displacement 10,000 tons, built of steel. Two sets of triple expansion engines, cylinders 34½ in., 57½



"S. S. Scott's Engines."

in., and 92 in. diam., by 5 ft. stroke, all cylinders are fitted with liners of close grained iron, and are steam-

jacketed, the pressure in each of the three jackets being regulated by a reducing valve, so that the most economical jacket pressure may be maintained. There is



"S. S. Scott's Boilers."

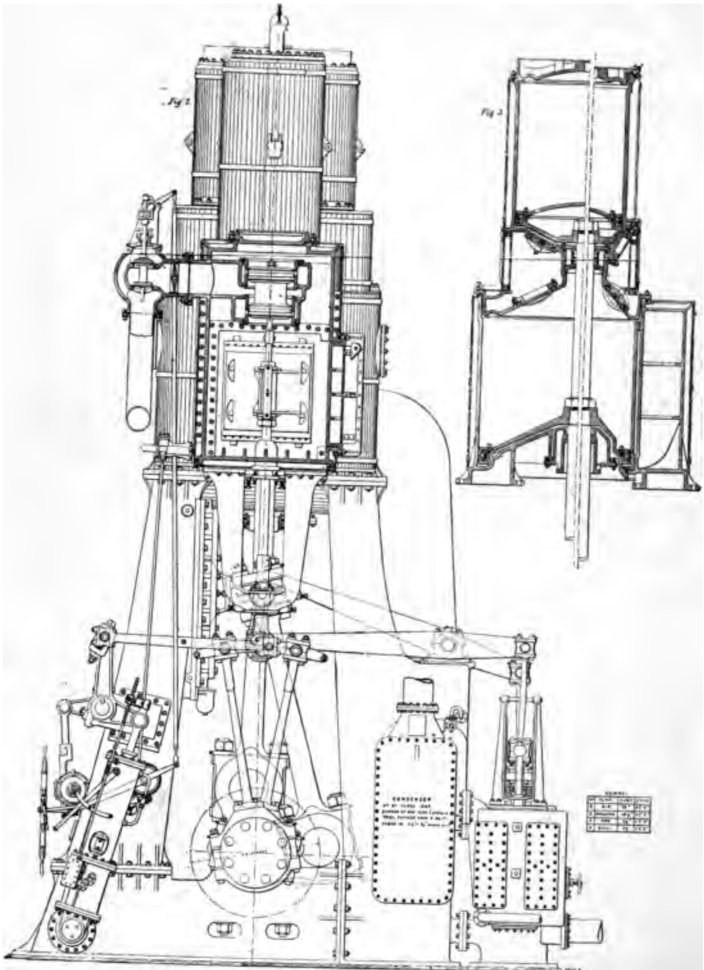
one piston valve on the high pressure cylinder, two on the intermediate, and one three ported slide valve for

the low-pressure cylinder. Weir's feed-water heaters and evaporators are fitted in the engine rooms. There are six steel double-ended boilers. each having six corrugated furnaces, grate surface 837 sq. ft., heating surface 22,964 sq. ft. Donkey boiler for a working pressure of 120 lbs., steam pressure in main boilers 170 lbs. I. H. P., 11,656, speed 19 knots, revolutions per minute 80, coal per horse-power per hour 1.5 to 1.6 lbs.

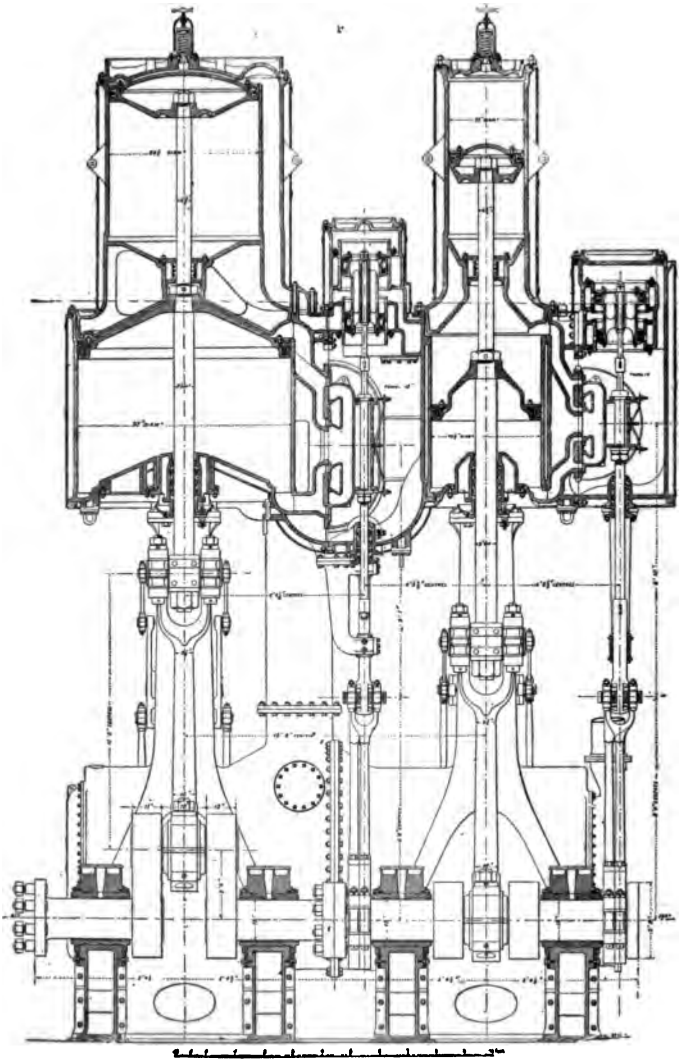
The steamship "Ophir", for the London and Australian trade, is the latest example of the first-class twin-screw steamer, built by R. Napier & Co., and went on her route November, 1891. Length over all 482 ft., between perpendiculars 465 ft.. beam 53½ ft., depth 37 ft., gross tonnage 6,900 tons, displacement at 24½ ft., draught 10,600 tons. Engines designed by A. C. Kirk. Two sets of triple expansion engines, cylinders 34 in., 51½ in. and 85 in. diam., by 4½ ft. stroke. They are inverted and direct-acting, and all the cylinders are steam-jacketed. The valve gear is of the ordinary link motion. The high pressure and intermediate cylinders have single piston valves, and the low-presure cylinder has a double-ported slide valve. Weir's feed water heaters, centrifugal circulating pumps, air and bilge pumps, worked by the main engines, auxiliary condensers, Brown's hydraulic starting and reversing gear. There are in addition to a distilling and auxiliary boiler

seven main boilers, in two compartments, which are 63 ft. apart. In the after one there are three double ended boilers, and in a recess in the forward bulkhead a distilling boiler, while in the fore compartment are two double ended boilers, one at either side, and two single ended boilers in the centre, placed back to back, grate surface 756 sq. ft., heating surface 26,004 sq. ft., steam pressure 160 lbs., test pressure 320 lbs. The fire rooms are so constructed that they can be worked with forced draft on the British Admiralty system. There are eight fans, each driven by a separate engine. Propellers 17 ft. diam., each has three blades of manganese bronze, pitch 23 ft., 3 in., cruising speed 18 knots, maximum 18¾ knots, maximum horse-power 11,400. When on a 500 mile trial, mean speed 15.8 knots, consumption 93½ tons of coal in 24 hours. Indicated horse-power 7.393, equal to 1.2 lbs. per horse-power per hour; consumption at full power and for all purposes on the ship about 1.5 lbs. per I. H. P. per hour.

The steamship "Buenos Aires", of Barcelona, is an example of another type of vessel. She was built in 1887 by Wm. Denny & Brothers, of Dumbarton. Length 410 ft., beam 48 ft., depth 32 ft. The engines were designed and patented by Walter Brock, and are of the quadruple-expansion tandem type, with two cranks at right angles, cylinders, 32 in. 46½ in., 64½ in. and 92



"S. S. BUENOS AYERS' ENGINES."

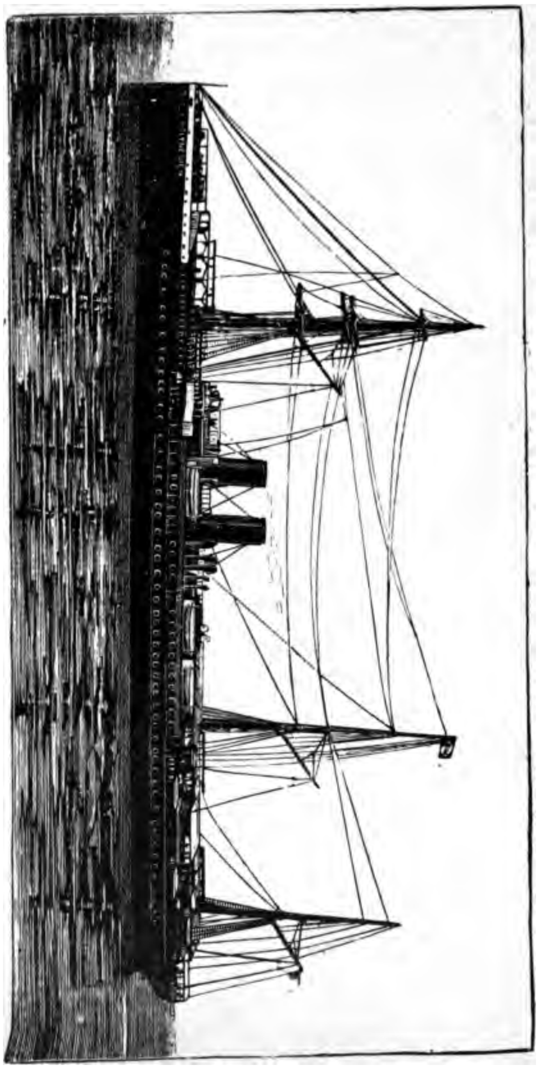


S. S. BUENOS "AIRES' ENGINES."

in. diam., by 5 ft. stroke, the lower part of the engine being of the ordinary construction. There were three double ended steel boilers, steam pressure 180 lbs., indicated horse-power 4,300, speed 15½ knots.

Many engines were altered to this plan. As examples, the large steamer "Tenasserim", belonging to the British and Burmese Steam Navigation Co., had compound engines 47 in. and 82 in. diam., by 3½ ft. stroke, with four single ended boilers for 60 lbs. steam pressure. These were removed in 1887, and new engines and boilers, on Brock's system, were fitted in the ship. The new engines had cylinders 24½ in., 37 in., 49 in., and 72 in. diam., by 3½ ft. stroke. And the new boilers were two double ended, suited for a pressure of 180 lbs. An increase in power of 40 per cent. was developed, with a corresponding increase in the speed of the vessel. Indicated horse-power 1,800.

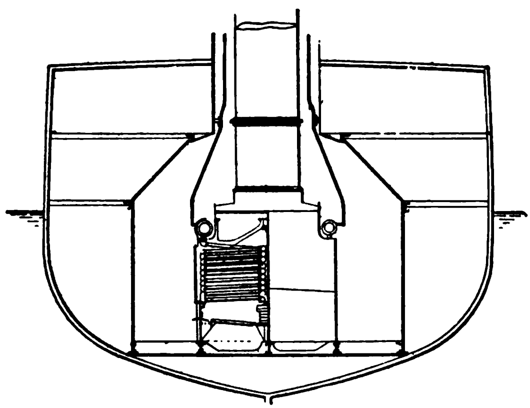
The "Kron Prinz", owned by the North German Lloyd Co., in 1887, had her machinery changed to the Brock system. This ship was 318 ft. long, 39½ ft. beam, and 31 ft. deep. Her old engines had cylinders 48 in. and 88 in. diam., by 4 ft. stroke, and four single ended boilers for 60 lbs. steam. In their converted form the engines have cylinders of 21½ in., 30½ in., 43 in., and 61 in. diam., by 4 ft. stroke. They are supplied with steam of 170 lbs. pressure, from two double ended



S. S. "AUSTRALIEN."

boilers, grate surface 173 sq. ft., heating surface 4,338 sq. ft., speed 13.19 knots, I. H. P. 1,700. In consequence of the greatly increased economy of the new engines, the owners were enabled to convert a considerable portion of the coal bunkers into carrying space.

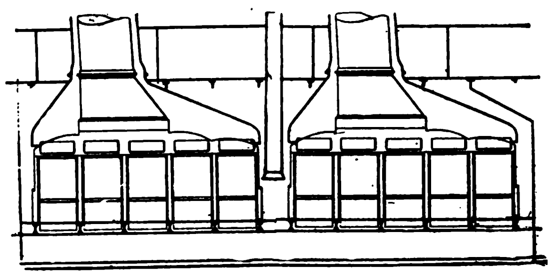
The steamers "Australien", "Polynesien", and "Tasmanien", illustrate the latest development of



SECTION OF S. S. "AUSTRALIEN."

French marine construction, being the newest additions to the fleet of the Messageries Maritime Co's. steamers for passengers and freight, between Marsille and Sydney, N. S. Wales. These steamers were built at the company's own works, near Marsille, and are 602 ft. long, 59½ ft. beam, and 44 ft. deep; displacement

8,638 tons, draught 22 to 26 ft. They are fitted with triple-expansion engines, cylinders 44 in , 67 in. and 106 in. diam., by 4½ ft. stroke, steam press 180 lbs., revolutions per minute 82, I. H.P., 7,650, speed 18 knots.

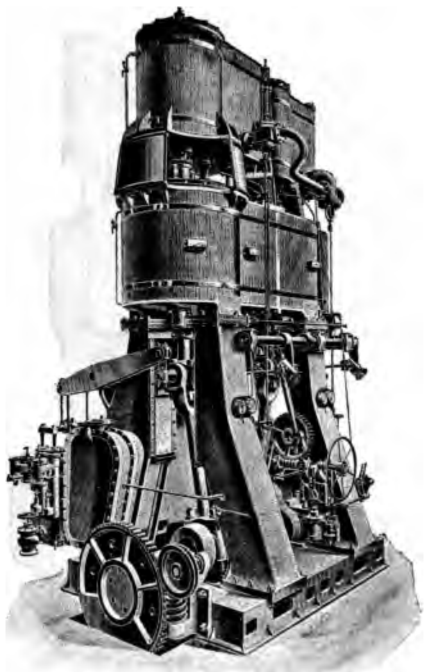


BOILERS OF S. S. "ATSTRALIEN."

These ships are fitted with twenty Belleville boilers, set back to back amidships, with a fireroom on each side, and the coal bunkers between them and the outside of the hull, grate surface 623 sq. ft., heating surface 23,-000 sq. ft. It is reported that these ships have attained a higher speed, and greater economy than was anticipa-ted by their designers, and that the boilers have done good service in this company's ships, replacing the Scotch boilers.

The steamer "Falls ot Inversnaid", fitted in 1888, with quadruple-expansion engines, by Rankin & Black-more, of Greenock, illustrates another type. This ship

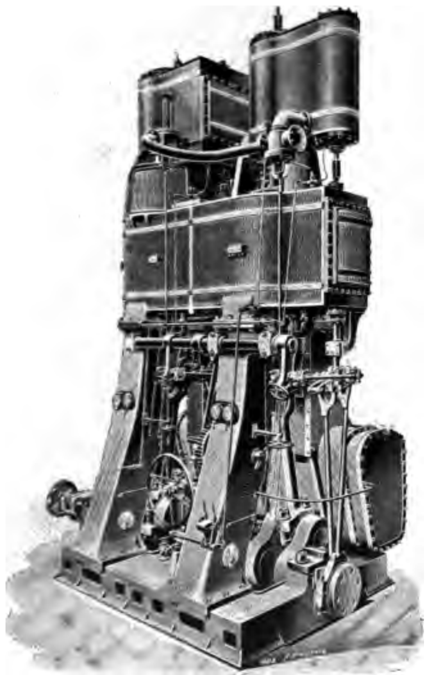
is 312 ft. long, 40 ft. 4 ins. beam, by 19 ft. 7 ins. deep, and was constructed to carry 4,000 tons dead weight,



ENGINES S. S. "INVERSNAID."

on a mean draught of 21 ft. The engines are on the tandem plan, similar to the White Star Line engines, with two cranks; cylinders 18 ins., 26 ins., 36 ins. and 52 ins.

diam., by 39 ins. stroke. There are two boilers, 13 ft. diam., by 11 ft. long, constructed for a working press-



ENGINES S. S. "INVERSNAID."

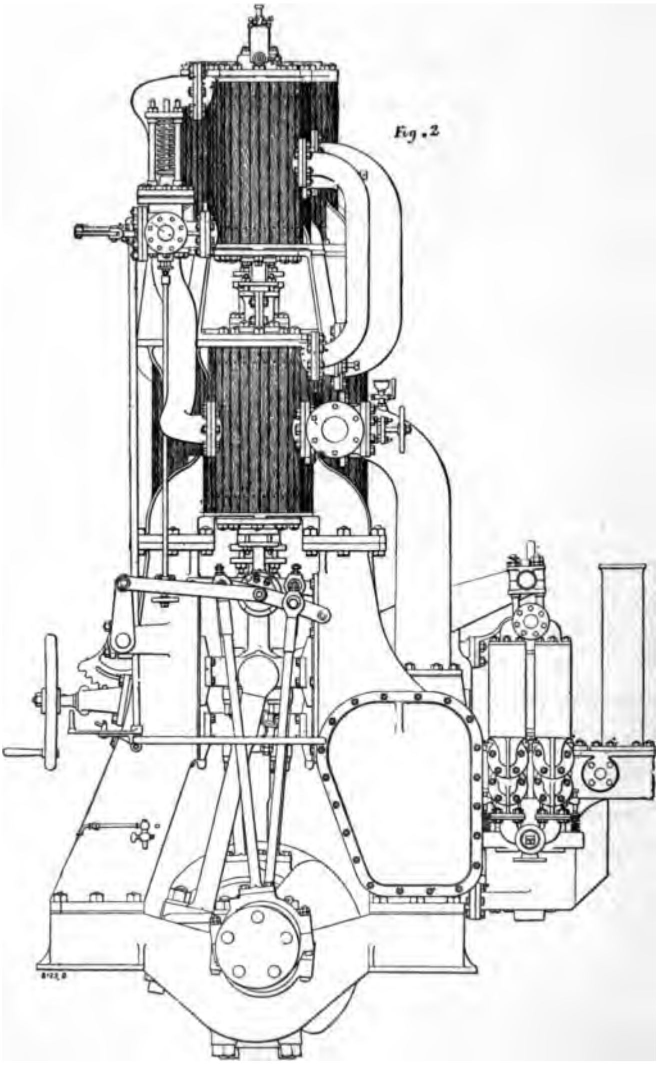
ure of 180 lbs., and fitted for forced draught into closed ashpits, with automatic valves to admit air, both above and below the furnace bars; fans worked by compound

Chandler engines. Speed 9¼ knots, on a consumption of 13 tons of coal per day.

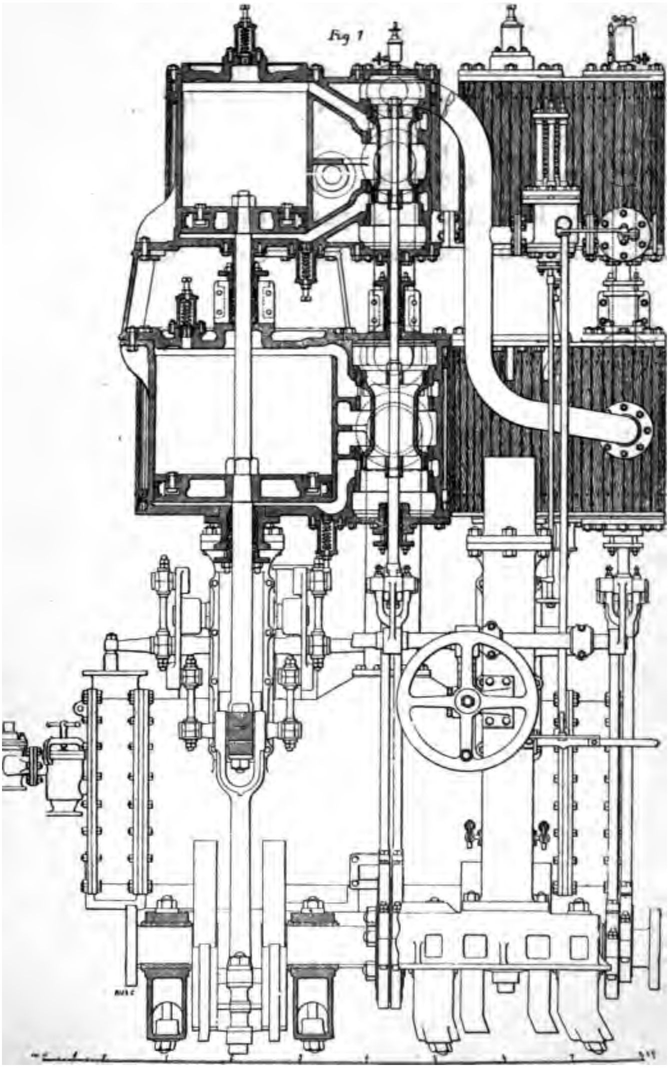
The builders of these engines claim that on the yacht "Myrtle", 163 ft. long, 20½ ft. beam, and 14 ft. deep, tonnage 318 tons, speed 12 knots, and with similar engines, built by them, cylinders 12 ins., 17 ins., 24 ins., and 34 ins. diam., by 24 ins. stroke, one two furnace boiler, and 180 lbs. steam, the consumption on a three hours run was 1.2 lbs. coal per indicated horse-power per hour.

They also claim that on the yacht "Rionnag-na-Mara", 170 ft. long, 21 ft. beam, 13½ ft. deep, 311 tons, speed 12 knots, and their three crank tandem engines, with three 7 ins. high-pressure, one 16 ins., one 22 ins., and one 34 ins. cylinder, by 2 ft. stroke, one two furnace boiler, for 180 lbs. pressure. The mean indicated horse-power was 412, on a three hour's trial, coal per hour 463.6 lbs., coal per horse-power 1.125 lbs., maximum horse-power at 113 revolutions, 528 H. P., and yet these engines did not have steam jackets, nor hot-blast.

The steamship "County of York", gives another example of quadruple-expansion engines. This ship was built in 1885, by the Barrow Shipbuilding Co., and is 235 ft. long, 38 ft. beam, and 25 ft., 7 ins. deep; carries 3,500 tons dead weight, speed 9.3 knots. The engines are of the two cranks, at right angles, tandem



"ENGINES OF THE YACHT MYRTLE."



"ENGINES OF THE YACHT MYRTLE."

type, cylinders 20 ins., 28½ ins., 40 ins., and 57 ins. diam., by 3 ft.. 6 ins. stroke. Propeller 16 ft. diam., by 18½ ft. pitch, revolutions 58 per minute. Two single ended boilers, with three corrugated furnaces in each, grate surface 99 sq. ft., heating surface 2,692 sq. ft., mean indicated horse-power 940. The engines are said to have proved exceedingly economical.

CHAPTER IV.

In 1820, when the British Admiralty first began to apply steam power to propel their ships of war, they used (as wc have seen on the "Comet", "Lightning", and "Meteor",) side lever engines, by Boulton and Watt. Previous to 1830, they possessed only a few small steamers, which were principally employed for the purpose of towing ships in and out of harbor, and other services on the coast, with an occasional voyage to Lisbon or Gibraltar. These vessels were built very strong, and although it became necessary in the first instance to employ them in the conveyance of the Mediterranean mails, on the adoption of steamers for that service, they were removed to other duty as soon as more competent vessels could be built expressly as packets.

About 1830, the Admiralty, having determined to add a small squadron of steam cruisers to the Navy,

gave directions for the construction of a steam ship of war at each of the Dockyards. In pursuance of this arrangement, the "Dee", "Phenix", "Salamander", "Rhadamanthus", and "Medea" were constructed. Length 206 ft., beam 32 ft., tonnage 835 tons, coal bunker capacity 320 tons, draught of water 14 ft. The engines for these ships were built by Maudslay & Field, of London. They were on the side lever plan, the two cylinders were each 54 ins. diam., by 5 ft. stroke. Morgan feathering paddle wheels on the "Medea", 24½ ft. diam., by 5 ft., 8 ins. face, steam jackets on the cylinders. Four flue boilers, speed from 8½ knots to 10 knots, according to draught of water, coal per day, at full power, 18 tons, 17 cwt., coal per horse-power, per hour, 8 lbs., best coal, 7 lbs.,

The "Medea" was fitted with disconnecting cranks, to allow the wheels to revolve when under sail.

The "Bernice", built in 1836, was 165 ft. long, 28 ft., 8 ins. beam, 20 ft. deep, tonnage 646 tons, two side lever engines, by Robt. Napier, cylinders 56 ins. diam., by 5 ft. stroke, revolutions per minute 22, paddle wheels 23 ft. diam., by 8½ ft. face, flue boilers.

During this decade, from 1830 to 1840, the side-lever engines continued to be used, but about the latter date, the direct-acting engine began to come into use, and before 1850 many types had been designed.

In Bourne's treatise on the Steam Engine, of 1851, in Plate I, he represents a comparitive view of direct-action engines, and says: "Direct action engines have of late years come into extended use in steam vessels, and their employment appears likely to become universal. They are less bulky and less weighty than side-lever engines. Most of the early devices were crude and unsatisfactory, but the excellent performance of the oscillating and double cross-head engines have redeemed the class from the disgrace that might otherwise have been expected to overtake it." The existing crop of direct-acting engines is divisible into five varieties: First, all those which have the connecting rod between the piston-rod and the crank; second, steeple engines which have the connecting-rod situated above the crank; third, the Siamese or double cylinder engine, as employed by Maudslay & Field; fourth, the double cross-head engine adopted by Bury & Fawcett, of Liverpool, and fifth, the oscillating engine, brought into favor by Penn, of London.

The "Thunderbolt" was built in 1842. Length 174 ft., beam 36 ft., depth 21 ft., tonnage 1000 tons. Two direct-action engines, by Robt. Napier, cylinders 67 ins. diam., by 5 ft. stroke, paddle wheels 26 ft. diam. by 7 ft., 10 ins. face, flue boilers.

The "Terrible," built during this period, furnishes

an example of the largest class of steam frigates propelled by paddle wheels, length 226 ft., beam 42½ ft., depth 27 ft. 3 ins., tonnage 1846 tons; engines, Maudslay & Field's double cylinder type, four cylinders each, 72 ins. diam. by 8 ft. stroke; paddle wheels 34 ft. diam. by 13 ft. face. One piston valve for two cylinders, separate double beat expansion valve, operated by cam motion and adjustable. There were four double-ended tubular boilers, with six furnaces in each.

Many vessels were built for the British Navy before 1850, having direct acting engines of these various types, but after that date the screw propeller began to be adopted for the propulsion of ships in preference to paddle wheels, and other types of engines came into use.

In 1836 F. P. Smith obtained a patent, dated May 31st, for an improved propeller for steam and other vessels, made to revolve under water in a recess or open space formed in the dead-wood of the run, forward of the rudder post. A small model was made and exhibited in operation.

The same year Mr. Smith and his friends constructed a boat of six tons, with an engine of about six H. P., and exhibited her on the Paddington Canal and the Thames. In September, 1837, Smith took this vessel from Blackwall to Gravesend and then along the coast to Ramsgate, Dover, Folkstone and Hythe. On

the 25th of the same month he returned to London in stormy weather, and made a speed of 6½ miles an hour. Her progress was watched by nautical and naval men who were loud in their praises. These favorable impressions reached the Admiralty and produced a visible effect there.

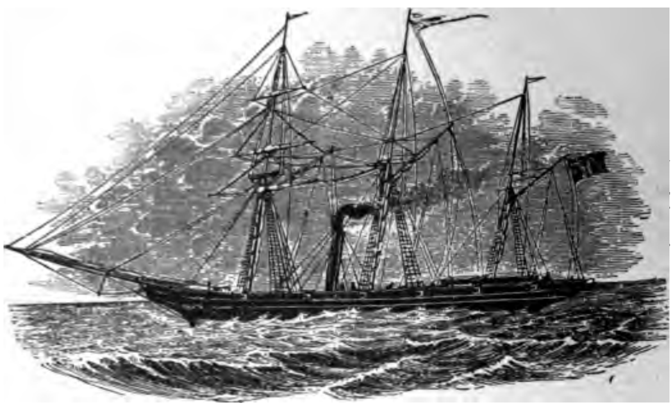
In March, 1838, the Admiralty requested Mr. Smith to have the vessel tried under their inspectors. Two trials were accordingly made which were considered satisfactory. Before finally deciding, however, upon the adoption of the propeller, the Admiralty considered it desirable that an experiment should be made with a vessel of at least 200 tons; and Mr. Smith and his associates resolved to construct the "Archimedes."

This vessel was 106 ft. long by 21 ft. beam, and 237 tons, and made her first trip in 1839. She was fitted with two engines of 80 H. P., her cost was £10,500 and her speed was 9½ knots.

After various trials and some changes, in April 1840, the Admiralty dispatched Capt. Chappell of the navy, and Mr. Lloyd the chief engineer of Woolwich Dockyard, to conduct a series of experiments at Dover, and the speed of the "Archimedes" was tested relatively with that of the mail packets on the Dover station. The result was a highly favorable report to the Admiralty, stating that the success of this new method of propul-

sion had been completely proved.

Immediately after these experiments were concluded the vessel was placed at the disposal of Capt. Chappell who, accompanied by Mr. Smith, performed with her the circumnavigation of Great Britain, visiting in their progress every sea-port of importance on the course. Everywhere the



"ARCHIMEDES."

vessel became an object of wonder and admiration. After this the "Archimedes" made a voyage to Oporto. This voyage was performed in 68½ hours, and was, at the time, held to be the quickest voyage on record. She also visited Antwerp and Amsterdam, passed through the North Holland Canal, and made a number of trips

to other places. She was next lent to Mr. Brunel, who performed various experiments with her at Bristol, after having fitted her with screws of several different forms. The result was considered so satisfactory that the "Great Britain", originally intended to be propelled by paddles, was altered to adapt her to the reception of a screw.

Meanwhile the Admiralty had determined upon adopting the screw for the service of the Navy, and in the merchant service an opinion had arisen equally favorable to its eligibility. In 1840 and 1841, the "Princess Royal" was built at Newcastle, the "Margaret" and "Senator" were built at Hull, and the "Great Northern", a vessel of 1500 tons burden, was laid down at Londonderry, in Ireland. All these were merchant vessels.

In 1841, the "Rattler", the first screw vessel built for the Navy, was laid down at Sheerness. This vessel which was 176 ft. long, 32 ft., 9 ins. beam, 200 horse-power, with Maudslay & Field's double cylinder geared engines, four cylinders 40 ins. diam., by 4 ft. stroke, revolutions 25 per minute, revolutions of screw, 100 per minute, tonnage 888 tons, was launched in the Spring of 1843. The screw was 9 ft. diam., by 11 ft. pitch, by 1 ft. 10 ins. long. In the years 1843, 1844 and 1845, an extensive series of experiments was made with the "Rat-

tler", upon screws of various forms, and under varying circumstances of wind and water. The performance of the vessel was found to be so satisfactory that the Admiralty ordered twenty vessels to be fitted with the screw, under Mr. Smith's superintendence. The screws introduced into these vessels were in every case double-threaded screws, set in the deadwood, after the fashion adopted in the "Archimedes" and the "Rattler."

On July 13th, 1836, John Ericsson, who had been in England since 1826, took out a patent for an improved propeller applicable to steam navigation, and during that year he made numerous experiments in London with a model boat, 2 ft. long, to determine the merits of his propeller. The results attained were considered satisfactory, and in 1837 a vessel 45 ft. in length, 8 ft. beam, and 3 ft. draught of water was built on the Thames, in order to test on a larger scale the merits of the invention. This vessel, the "Francis B. Ogden," (called after the United States Consul in Liverpool,) was tried on the 30th April in the same year. Her success was very remarkable. She at once attained a speed of 10 miles an hour.

A schooner of 140 tons was towed by her at the rate of 7 miles an hour. Ericsson invited the Lords of the Admiralty to witness the performance of his vessel. They embarked on the Admiralty barge at Somerset

House, and the "Ogden" towed them to Limehouse and back at a speed of 10 miles an hour. He received no encouragement from the Admiralty; as he discovered that the surveyor of the navy was of the opinion that, as the propelling power was applied at the stern, the vessel could not be steered in an efficient manner.

In the winter of 1837 a canal boat called the "Novelty" was fitted with Ericsson's propellers, and was set to ply on the canal between Manchester and London. The propellers were only 2½ ft. in diam., driven by a ten-H. P. engine, yet the boat made a speed of 8 to 9 miles an hour.

At this time Ericsson came into communication with Capt. R. F. Stockton, of the United States Navy, who was so much pleased with the performance of the experimental boat, that he ordered an iron vessel, 70 ft. long, 10 ft. beam, and fifty-H. P., to be constructed at Liverpool, and fitted with the new propeller. This vessel, which was called the "Robert F. Stockton," was taken to London and tried on the Thames in January, 1839. She towed four laden coal barges lashed along side of her at the rate of 5½ miles an hour. In April, 1839, the "Stockton" left England, and proceeded under sail to America.

In the latter part of 1839 Ericsson proceeded to America, where he remained, and in 1843 introduced

his propeller on the United States Steamer "Princeton."

When Ericsson left England he consigned his interests to Count Rosen, and in 1843 the Count received an order from the French Government to fit a 44 gun frigate, the "Pomone," with a propeller on Ericsson's plan, and with two engines of 220 H. P., which were to be beneath the water line, as in the case of the "Princeton," cylinders 46 in. diam. by 46 in. stroke, revolutions 40 per min.

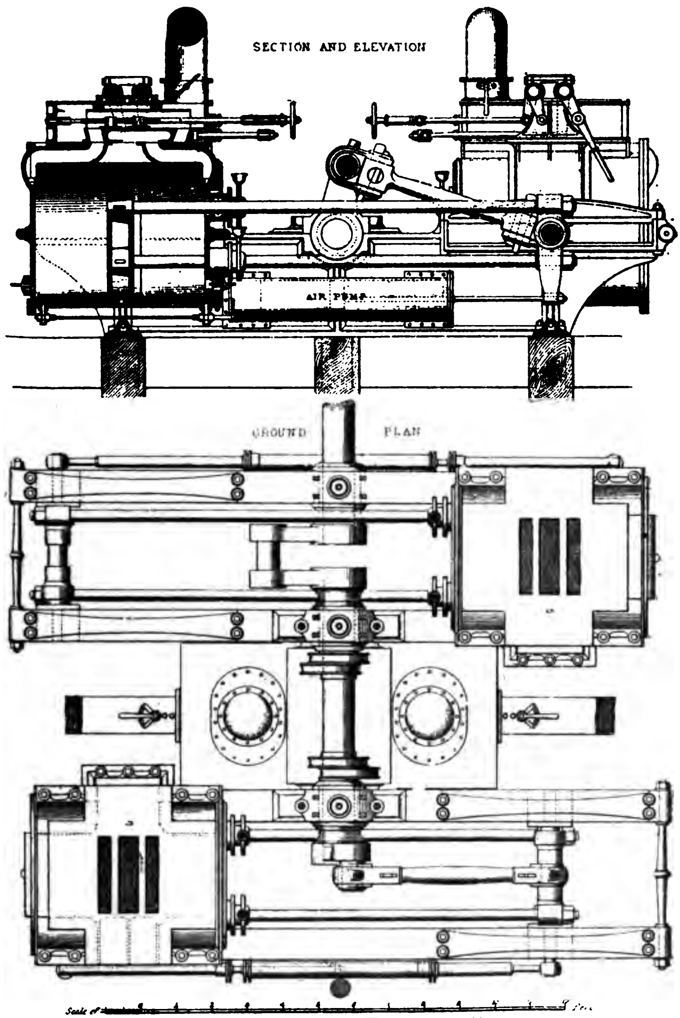
In 1844 the British Government gave Count Rosen instructions to fit the "Amphion" frigate with a propeller and with engines of 300 H. P., which were to be kept below the water line in the manner of the engines of the "Pomone."

The engines of these vessels were the first engines in Europe which were kept below the water line.

They were also the first direct-acting horizontal engines, employed to give motion to the screw.

The air pumps, which were also horizontal, were double acting, and were furnished with canvas valves to diminish the shock incident to the shutting of large apertures where so high a speed had to be maintained.

Both vessels were completely successful. The speed engaged to be given was five knots an hour. A speed of about seven knots an hour was actually obtained.



"AMPHION'S ENGINES."

The "Amphion" was 177 ft. long, 43 ft. 2 ins. beam, 2050 tons displacement, two cylinders 48 ins. diam. by 4 ft. stroke, revolutions 48 per min., short slide valve balanced, with adjustable cut off valve on the back. The engines were built by Miller, Ravenhill & Co., and designed by Mr. Holm. The "Pomone's" engines were also designed by Mr. Holm.

It will be observed that when Smith introduced his propeller on the "Rattler" he adopted geared engines, with the propeller shaft making four revolutions for one of the crank shaft. This was due to the fear then existing in England that the air pumps would not work satisfactorily at a high speed.

Ericsson, on the contrary, on the "Princeton," "Pomone," and "Amphion," connected the engines direct to the propeller shaft, and in consequence, the contest between the advocates of geared and direct action engines followed, and continued many years until rubber valves for air pumps were perfected, when the geared engine disappeared.

John Bourne, in his treatise on the Screw Propeller, edition of 1867, published two large plates, one showing a comparative view of geared screw engines, and the other showing a comparative view of direct-acting screw engines, from which it appears that a great amount of ingenuity was called forth in designing the various

types of screw engines. Nearly all these types of engines have become obsolete, and have been supplanted by the direct-acting vertical engine which has less friction than horizontal engines.

The engines of the "Miranda," "Dauntless" and "Duke of Wellington," are examples of the geared engines in vogue from 1850 to 1860.

The "Miranda" was 196 ft. long, 34 ft. beam, draught of water 13½ ft., tonnage 1039 tons; engines, two horizontal, cylinders 56 ins. diam. by 3 ft. 9 ins. stroke, geared 2.43 revolutions of propeller to one of crank shaft, revolutions of engines 32 per min.

The "Dauntless" was 218 ft. long, 39 ft. 9 ins. beam, draught 17 ft., tonnage 1570 tons; engines two horizontal; cylinders 84 ins. diam. by 4 ft. stroke; geared 2.276 to one; revo. of engines 30 per min.; speed 10 knots an hour.

The "Duke of Wellington,"—line of battle ship, and flag ship in the Baltic during the Russian War in 1854—was 240 ft. long, 60 ft. beam, draught 24 ft., tonnage 3760 tons; engines, two horizontal; cylinders 94 ins. diam. by 4 ft. 6 ins. stroke; geared, revo. of engines 30 per min.; of propeller 67 per min.; speed 10.7 knots; propeller 18 ft. in diam. by 16¼ ft. pitch. These engines were built by Robt. Napier of Glasgow.

The horizontal trunk engines, introduced by Penn

of London, were extensively used. The first examples of this class were constructed for the "Arrogant" and "Encounter" in 1848; two cylinders 60 ins. diam.; trunks 24 ins. diam.; equal to a cylinder 55 ins. diam. by 3 ft. stroke.

The armour plated ship "Warrior," built in 1861, length 380 ft., beam 58 ft. 3 ins., tonnage 6109 tons, draught 26 ft., also had Penn's horizontal trunk engines, cylinders 104 ins. diam. by 4 ft. stroke; speed 14.4 knots; steam pressure 22 lbs.; propeller 24½ ft. diam. by 30 ft. pitch; 54 revo. per min.

The troop ship "Himalaya," built 1856, was 340 ft. long, 46 ft. beam, tonnage 3550 tons, draught 17 ft.; Penn's horizontal trunk engines, cylinders 78 ins. diam. by 3½ ft. stroke; steam pressure 18 lbs.; I. H. P. 2050; speed 13.78 knots.

The "Bellerophon,"—iron clad—built 1865, and regarded as the most perfect example of E. J. Reed's system, was 300 ft. long, 56 ft. beam, tonnage 4270 tons; draught 21 ft.; speed 14.27 knots; Penn's horizontal trunk engines, 6000 I. H. P.

The iron clads, "Agincourt," "Minotaur" and "Northumberland," of 6220 tons, had engines of 1350 nominal H. P., or about 8000 I. H. P., were completed about 1865; speed 15 knots.

The first had horizontal back-acting engines by

Maudslay, and the last two had Penn's horizontal trunk engines. The engines of these vessels were designed to work with great economy, and to indicate six times their nominal power; these advantages being obtained by means of superheating, great expansion and surface condensation.

In 1870 the twin screw iron-clad ships, "Vanguard," "Invincible" and "Iron Duke," sister ships, were tried. They were 280 ft. long, 54 ft. beam and 5560 tons displacement; I. H. P. 5000; speed about 14 knots.

In 1877 the "Alexandra," twin screw iron-clad ship was tried. She was 325 ft. long, 63 ft. 8 ins. beam and 9432 tons displacement; I. H. P. 8615; speed 15 knots; propellers 21 ft. diam. by 22 ft. 3 ins. pitch.

In 1877 the twin screw steel despatch vessel "Iris" was tried. She was 300 ft. long, 46 ft. beam, draught 19 ft. 9 ins.. displacement 3750 tons. The engines by Maudslay & Field, are direct-acting horizontal tandem compound. There are in all four high pressure cylinders 41 ins. diam., and four low pressure, 75 ins. diam. by 3 ft. stroke, two surface condensers, two propellers 18 ft. diam. by 18 ft. 8 ins. pitch; twelve tubular boilers with brass tubes 6½ ft. long, 3¼ ins. diam., grate surface 700 sq. ft., fire surface 18,700 sq. ft. On the first trial the steam pressure was 62 lbs., revo. 90 to 91 per

min., speed 16 knots an hour, consumption 2.7 lbs. per I. H. P. per hour; I. H. P. 7088.

After some experiments had been made with the screws, another trial was made in July 1878, with the propeller 16 ft. 3 ins. diam. and 20 ft, pitch, and the surface of the blades reduced 25 per cent.; the speed was then 18.57 knots and the I. H. P. 7714; revo. 97 per min.

This great improvement in the speed of the "Iris," and her good maneuvering qualities, attracted a great amount of attention and the results obtained formed a basis for future guidance.

The sister ship "Mercury" was similarly fitted.

The twin screw iron clad, "Inflexible" was tried in 1878. She was 324 ft. long, 75 ft. beam, draught 21 ft., displacement about 11,000 tons, I. H. P. 8407. Engines by John Elder & Co. of Glasgow, are compound, each having one high-pressure cylinder 70 ins. diam., and two low-pressure 90 ins. diam. by 4 ft. stroke. There are 8 double and 4 single ended boilers, steam 62 lbs., speed 14.75 knots, consumption 2 lbs. coal per I. H. P. per hour; two propellers 20 ft. diam. by 23 ft. pitch.

In 1874 J. Scott Russell designed the engines for the Russian frigate, "General Admiral." They were vertical compound, built by Baird at St. Petersburg;

cylinders 92 ins. and 130 ins. diam. by 4 ft. stroke; steam 60 lbs. press.; cylinders steam jacketed. These were among the first large vertical engines for war ships.

The torpedo boats all had vertical engines.

In 1890 the Russian twin screw iron clad battle ship "Sinope," was tried off Sevastopol on the Black Sea. This ship was built at Nicholaeff, and the machinery was constructed by R. Napier & Sons of Glasgow, and fitted on board at Nicholaeff.

The success of the well known "Aberdeen" induced the Russian Admiralty, as early as 1884, to investigate the merits of the vertical triple-expansion engines, with a view to adopting them in their navy, and they entered into negotiations with Napier & Sons, the result being that the design and construction of the engines for the "Sinope" were intrusted to them,

These engines are of special interest as being the first triple-expansion engines ordered for a war ship, and so thoroughly were the authorities convinced that this was the engine of, at least, the immediate future, that, shortly afterwards, the construction of three sets of triple-expansion engines for the gunboats "Taporosets," "Chernomenetz" and "Donetz" was intrusted to Messrs. Napier also. This machinery was fitted on board the boats by the Russian Admiralty at Nicholaeff where the vessels were built. They have been at work

for some time, the engines working with marked economy and success.

The "Sinope" is 339 ft. 6 ins. long, 69 ft. beam, draught 26 ft. 6 ins., displacement 10,000 tons. Two sets of vertical triple-expansion engines, cylinders 44 ins., 63 ins. and 95 ins diam. by 45 ins. stroke, brass surface condensers and circulating pumps, wrought iron columns, Kirk's valve gear worked from the connecting rods, piston valves.

There are 14 single ended tubular boilers with 3 furnaces in each, grate surface 1064 sq. ft., heating surface 26,222 sq. ft., steam pressure 125 lbs. On the six hours full power trial the indicated power was 12,803 I. H. P., speed 17 knots, consumption 1.35 lbs. coal per indicated horse power per hour.

In Sept., 1891, the British twin screw, second-class cruiser "Thetis," built by J. & G. Thomson, Glasgow, made an eight hours trial.

The "Thetis" is a sister ship to the "Terpsichore" and "Tribune," built by the Thomson's, who contracted for the construction of three of the 27 second-class cruisers, ordered under the Naval Defence Act,

The "Thetis" is 300 ft. long, 43 ft. beam, 22 ft. 9 ins. deep, draught 16½ ft., displacement 3400 tons. This ship belongs to what is known as the protected deck class. The engines are of the triple-expansion

vertical inverted type, now so universally adopted in the British Navy, in contra-distinction to the horizontal type, which held their place from the beginning of screw propulsion in the Navy, until very recently. Each set of engines is placed in a separate engine room with a fore and aft bulk-head dividing them, and each is in all respects similar.

The cylinders are 33½ ins., 49 ins. and 74 ins. diam. by 3 ft. stroke; the cylinders are steam jacketed, the jackets being formed by the cylinder lincrs, piston valves working in seperate liners are fitted to the high pressure, and intermediate cylinders, and a flat double-ported valve with a relief ring at the back is fitted to the low pressure cylinder, surface condensers are built of brass plates for lightness, two evaporators and distillers: steam at 155 lbs. pressure is supplied by three double ended and two single ended and boilers, grate surface 573 sq. ft., heating surface 15,404 sq. ft., forced draught in air-tight fire room, pressure allowed 1¼ in. of water, actual 75 in., maximum indicated horse power 9400, at 138 revolutions per minute, speed, 20 knots, air pressur in the fire-room .75 ins., I. H. P. per ton of machinery and water 13.

In November, 1891, the British twin-screw first-class cruiser "Edgar", constructed in the Devonport Dockyard, was tried for four hours at full power, with

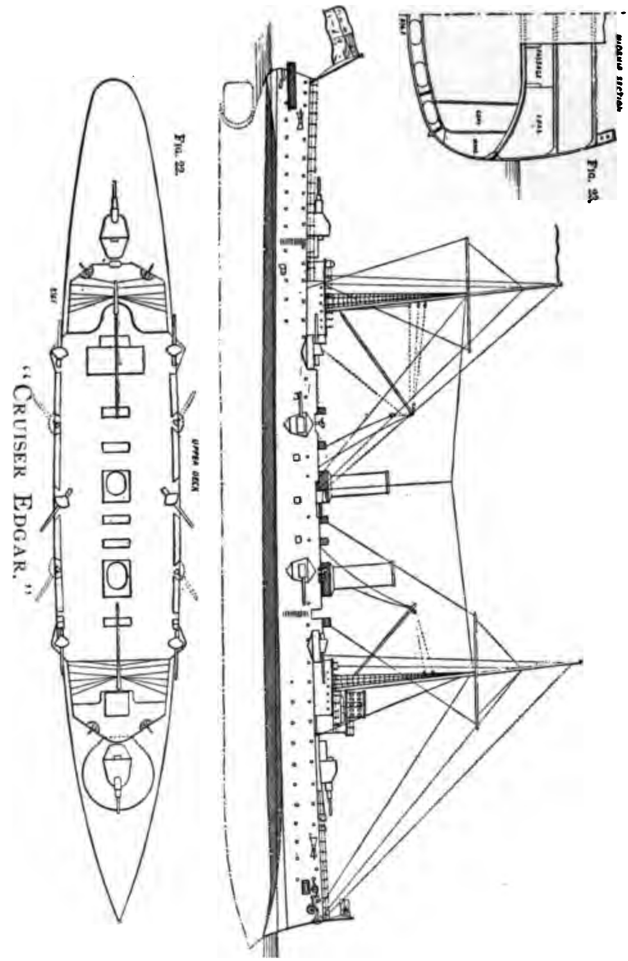
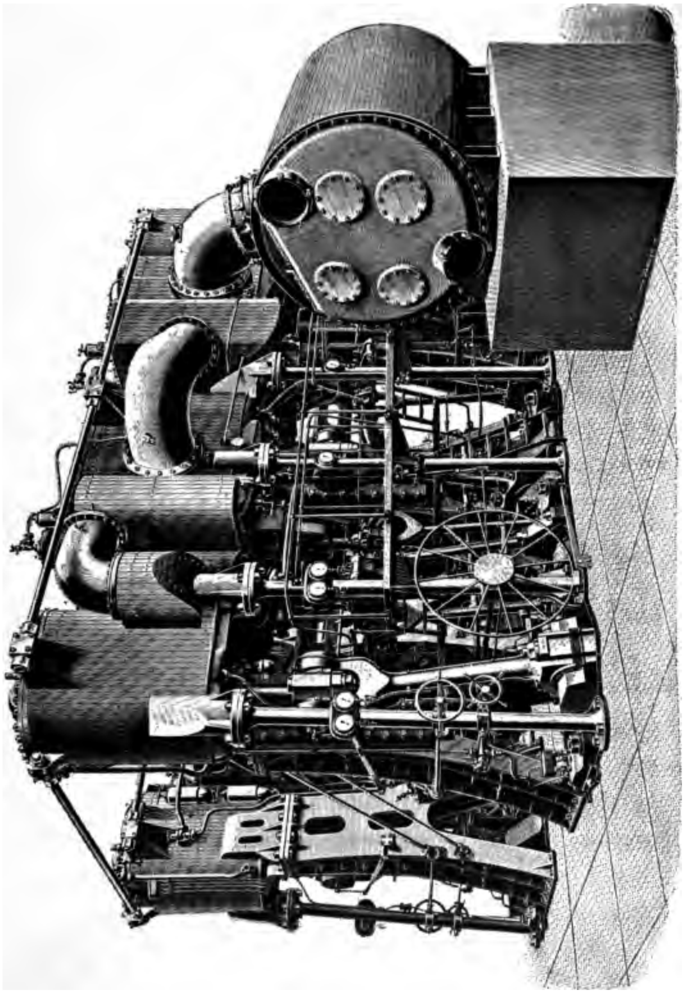


FIG. 22.

FIG. 23.

"CRUISER EDGAR."



"ENGINES OF THE CRUISER EDGAR."

forced draft of 1 inch water pressure. This ship is the first of her class of nine vessels, to be commissioned under the Navel Defence Act, and is 360 ft. long, 60 ft. beam, draught 23 ft., displacement 7350 tons, indicated horse power 12,463, speed 20.97 knots. The two sets of engines were built by the Fairfield Co., Glasgow, and are triple-expansion vertical engines, with three cylinders and three cranks. The cylinders are 40 ins., 59 ins., and 88 ins. diam., by 4 ft., 3 ins. stroke, steam-jacketed. The high-pressure cylinders are each fitted with a liner of forged steel, and the intermediate and low-pressure cylinders are fitted with cast iron liners, piston valves on the high-pressure, and double ported slide valves on the intermediate and low-pressure cylinders. Steam is supplied by four double ended boilers, each with eight furnaces, and one single ended auxiliary boiler with three furnaces, grate surface 868 sq. ft., heating surface 25,411 sq. ft., steam pressure 155 lbs. The engines and boilers are well designed, and they indicate the best practice of to-day in high-power machinery. Contract H. P. with forced draft 12,000, actual 13,000, contract H. P., with natural draft 10,000, actual 10,170. I. H. P. per ton of machinery 11.35, piston speed 888 ft. per minute, revolutions per minute 104.5, contract pressure in the fireroom 1 in., actual .7 in.

The British protected cruiser "Blake" was built

at Chatham Dockyard, and the machinery was built by Maudslay, Sons & Field, of London. The vessel is of 9000 tons displacement at 25 ft., 9 ins. mean draught. Her length is 375 ft., beam 65 ft., engines 13,000 H. P., with natural, and 20,000 with forced draught. They consist of four distinct sets of triple-expansion inverted cylinder engines, and occupy, with boilers, etc., nearly two-thirds the length of the ship. They are placed in four separate compartments, two sets being coupled together on the starboard and port sides respectively for driving each screw. There are four high-pressure cylinders. 36 ins. in diam., four intermediate cylinders, 52 ins., and four low-pressure cylinders, 80 ins., with a stroke of four feet; revolutions 90 to 105 per minute; two propellers, each 18 ft., 3 ins. diam., with a mean pitch of 24 ft., 6 ins. Surface condenser for each set of engines, air pumps worked from the main engines; independent centrifugal circulating pumps; steam of 125 lbs. is furnished by six main double-ended boilers, having four furnaces at each end, and one auxiliary boiler; grate surface 863 sq. ft., heating surface 26,936 sq. ft. Forced draught is produced by twelve 5 ft., 6 ins. fans, three being placed in each fireroom. The estimate was that this ship would be able to steam continuously for long periods, and over great distances, at 20 knots per hour, and with forced draught she was to be able to at-

tain 22 knots when occasion required. But these high results have not been obtained on account of the boiler tubes leaking when under forced draught. The speed on the early trial was 19.12 knots, but of late on the sister ship "Blenheim", when under forced draught, the speed was 21.6 knots per hour, and still better rerults are expected by using the Chatham ferrules, in order to protect the ends of the boiler tubes.

The British Admiralty have lately adopted three types of tubulous boilers for torpedo boats. Messrs. Thorneycroft & Co. will fit their type of boiler in one boat.

Messrs. Yarrow & Co. are also introducing water tube boilers in some they are building. Messrs. Laird have also included water tube boilers in their contract with the Admiralty, but they have gone abroad for their design, (presumably Belleville boilers) in order to test the efficiency of these types.

The Argentine cruiser "Neuvo De Julio," constructed by Armstrong, Mitchell & Co., Newcastle, from designs by their naval architect Philip Watts, arrived in New York April 17th, 1893, to be present at the Naval Review there on April 27th, and is considered the fastest cruiser yet constructed.

She is 350 ft. long between the perpendiculars, 44 ft. beam, 16½ ft. mean draught, load displacement

3500 tons, contract horse-power with natural draught 9,000 and with forced draught 14,500 respectively. She has twin screws driven by two sets of triple-expansion four cylinder engines, built by Humphrys, Tennant & Co. of London. Each set of engines has two low-pressure cylinders 66 ins. diam., one intermediate cylinder 60 ins. in diam., and one high-pressure cylinder 40 ins. in diam. and 30 ins. stroke.

Their are eight single ended boilers, contract speed with natural draught 21½ knots, with forced draught 22½ knots; speed on trial without forcing 22.74 knots with 14,500 I. H. P. Coal bunker capacity 800 tons, which will enable the vessel to steam 10,000 knots at the most economical speed.

CHAPTER V.

About 1848, the steamers "Washington" and "Hermann" commenced to run between New York and Bremen. They were 236 ft. long, 39½ ft. beam, 31 ft. deep, average draught 19½ ft., tonnage 1750 tons. They had two side-lever engines, cylinders 72 ins. diam., by 10 ft. stroke, paddle-wheels 34 ft., 8 ins. diam., by 7½ ft. face, revolutions per minute 11, steam pressure 12 lbs., cut off at 3 ft., 4 ins.; two iron flue boilers side by side, grate surface 182 sq. ft., heating surface 5760 sq. ft., fan blast under grate, consumption of bituminous coal per hour 3920 lbs., speed 11 knots.

In 1850, the steamer "Franklin", and 1851, the "Humboldt commenced to run between New York and Havre. The first was 2400 tons, and had two side lever engines, cylinders 93 ins. diam., by 8 ft. stroke, and

fonr iron flue boilers. The second was 2850 tons, with side lever engines, cylinders 95 ins. diam., by 9 ft. stroke, both built at the Novelty Works, New York. Their average voyages between New York and Cowes was about 12 days, 21 hours. The "Franklin" was lost on Long Island, in 1854, and the "Humboldt" was lost near Halifax in 1853.

The "Arago" and "Fulton" were built, and took their place in 1855–56. The "Fulton" was 290 ft. long, 42 ft., 4 ins. beam, 31½ ft. deep, tonnage 3000 tons. She had two inclined oscillating engines, cylinders 65 ins. diam., by 10 ft. stroke; built at the Morgan Iron Works, New York. Paddle wheels 31 ft. diam., by 9 ft. face, two of E. W. Smith's double furnace flue and tube boilers, draught 17½ ft.

The "Arago" was about the same tonnage as the "Fulton", and had oscillating engines, built at the Novelty Iron Works, New York.

On the breaking out of the Rebellion, in 1861, the line was withdrawn and the ships went into the service of the U. S. Govt. After the war the "Arago" was sold to the Peruvian Govt., and the "Fulton" was broken up.

In 1857 the steamship "Vanderbilt" was put on the New York, Southampton and Havre Line, establish- by C. Vanderbilt. She was a wooden ship, built by J.

Simonson, 340 ft. long, 49 ft. beam, 33ft. deep, draught loaded 20 ft., tonnage 4,000 tons. She had two overhead beam engines, cylinders 90 ins. diam. by 12 ft. stroke,

COMMODORE VANDERBILT.

paddle wheels 41 ft. diam. by 10 ft. face. Four return tubular boilers, grate surface 600 sq. ft., heating surface

18,000 sq. ft., steam pressure 18 lbs., superheated by high steam chimneys and cut off at half stroke; revo. 17 per min., average speed at sea 12½ knots, consumption of coal per day 100 tons.

The steamers "North Star," "Northern Light," "Ariel" and "Ocean Queen," were afterwards added to the line, and they continued to run until 1861, when the war interfered. These ships all had beam engines.

In 1855 the Long Island Sound steamboats, "Plymouth Rock," "Commonwealth" and the "Metropolis" came out. The "Plymouth Rock" ran on the Stonington Line, and was 325 ft. long, 40 ft. 6 ins. beam, and 12 ft. 6 ins. deep. She had a beam engine, built by the Allaire Works Co., N. Y., cylinder 76 ins. diam. by 12 ft. stroke, paddle wheels 36 ft. 10 ins. diam. by 10 ft. face, two return flue boilers on the guard, grate surface 182 sq. ft., heating surface 4,900 sq. ft., fan blast, steam 30 lbs., cut-off at half stroke, steam chimneys.

The "Commonwealth" ran on the Norwich Line, and was similar to the "Plymouth Rock" engine built at the Morgan Iron Works, N. Y.

The "Metropolis" ran on the Fall River Line, and was 342 ft. long, 45 ft. beam and 16 ft. deep, tonnage 2108 tons. Beam engine built at the Novelty Works, N. Y., cylinder 105 ins. diam. by 12 ft. stroke, paddle wheels 40 ft. diam. by 13 ft. face. Four vertical tubular

boilers on the guards, grate surface 294 sq. ft., heating surface 12,000 sq. ft., fan blast used on the latter part of the passage, steam pressure 24 lbs., cut-off at 4½ ft. by Allen & Wells cut-off, revo. 15½ per min., speed 17.8 miles an hour.

In 1860 the "Seth Grosvenor" for Liberia came out. She was 96 ft. long, 16 ft. 8 ins. beam, 5 ft. 2 ins. deep, tonnage 84 tons, draught 3 ft. 6 in.; she had a steeple engine, built by the Allaire Works Co., N. Y., cylinder 28 ins. diam. by 3 ft. stroke, paddle wheels 13 ft. 6 in. diam. by 3 ft. face; Sewell's surface condenser, the first ever built for a ship, surface 276 sq. ft. One flue and tubular boiler, grate surface 22.5 sq. ft., heating surface 540 sq. ft., steam pressure 25 lbs., cut-off at half stroke, revolutions 27 per min., speed 13½ miles an hour, consumption 125 lbs. coal per hour.

In 1860 the coasting steamer "R. R. Cuyler," for the New York and Savannah trade, came out. She was 235 ft. long, 32½ ft. beam, 16 ft. 4 ins. deep, tonnage 1800 tons, draught 16 ft.; single upright engine, built by the Allaire Works Co., N. Y., designed by John Baird, cylinder 70 ins. diam. by 4 ft. stroke, slide valves with cut-off valve on the back, steam pressure 25 lbs., cut-off adjustable, screw propeller 16 ft. diam. by 23½ ft. pitch, four blades.

Two tubular boilers with steam chimneys, grate

surface 172.5 sq. ft., heating surface 6254 sq. ft., speed 13 knots, revo. 60 per min.

In 1861 the coasting steamer "John P. King," for the New York and Charleston trade, came out. She was 235 ft. long, 37 ft. beam and 21 ft. deep, draught 12 ft., tonnage 1550 tons. She had a single beam engine, built at the Allaire Works, N. Y., cylinder 71½ ins. diam. by 12 ft. stroke; Sickels' adjustable cut-off, paddle wheels 28 ft. diam. by 10 ft. face. Two round flue boilers with high steam chimneys, grate surface 217 sq. ft., heating surface 5422 sq. ft., revo. 22 per min., steam 25 lbs., speed 13 knots, consumption about 30 tons of coal per day.

This ship was sold to the U. S. Government, and known during the war as the "Rhode Island"; after the war she was sold again, and known as the "Charleston."

In 1862 the steamer "Eagle" came out. She was built to take the place of the "Rhode Island." She was of the same dimensions; the cylinder was 75 ins. diam. by 12 ft. stroks, and the paddle wheels 30 ft. diam.; the boilers were 1 ft. longer, but in other respects the same; steam 25 lbs., revo. 20 per min., cut-off Sickles' adjustable, speed 13 knots.

In 1861 the tow-boat "Thomas Freeborn" came out. She was 150 ft. long, 25 ft. 4 ins. beam, and 9 ft.

deep, tonnage 340 tons, draught 5 ft. 9 ins. Single beam engine, built at the Allaire Works, N. Y., cylinder 40 ins. diam. by 8 ft. stroke, paddle wheels 20 ft. diam. by 7 ft. 6 ins. face; one return flue boiler, grate surface 61.5 sq. ft., heating surface 1457 sq. ft., steam pressure 30 lbs., cut-off at half stroke, revo. 30 per min., when towing 22 per min., speed 16 miles.

In 1861 the ferry boats, "Kings County" and "Suffolk County," for the New York and Long Island City ferry came out. They were 158 ft. long, 32 ft. beam and 11 ft. 10 ins. deep. They had single beam engines, built by the Allaire Works Co., cylinders 34 ins. diam. by 9 ft. stroke, paddle wheels 19 ft. diam. by 6 ½ ft. face. One cylindrical flue and tubular boiler, grate surface 44.5 sq. ft., heating surface 2716 sq. ft., steam pressure 28 lbs., cut-off Sickels' adjustable, revo. per min. 26, speed 13 miles per hour.

On these boats the cut-off was used as a throttle; when going with the tide the steam was cut off short, and when going against the tide the cut-off was lengthened so that the boat would cross in about the same time; the consumption of coal was very moderate.

In 1861 the Staten Island ferry boats, "Clifton" and "Westfield," to run in connection with the railroad on the Island to New York, came out. They were 224 ft. long, 34½ ft. beam and 13 ft. deep, tonnage 977

tons. They had a single beam engine, cylinder 50 ins. diam. by 10 ft. stroke, paddle wheels 22 ft. diam. by 9 ft. face; two return flue boilers, grate surface 97 sq. ft., heating surface 2706 sq. ft., steam pressure 30 lbs., cut-off at half stroke, revo. 26 per min., speed 16 miles an hour.

The boats were the first to have a saloon on the upper deck, and to have the buckets on the paddle wheels half the length of the face, and staggered in order to prevent the jar, and the boats when under way were in fact very steady.

They were sold to the U. S. Government to run between Annapolis and Havre de Grace, and two others, "Clifton" No. 2 and "Westfield" No. 2, were built to take their place.

In 1862 the China steamboat, "Hu-Quang," for the Yang-Tse-Kiang River service, came out. She was built by H. Steers; was 290 ft. long, 36 ft. 8 ins. beam and 14 ft. deep, tonnage 1510 tons, draught 9 ft. She had a single beam engine with single poppet valves, built by the Allaire Works Co., N. Y., cylinder 76 ins. diam. by 12 ft. stroke, with Sickels' adjustable cut-off, paddle wheels 28 ft. diam. by 11½ ft. face; two round flue boilers with steam chimeys 20 ft. high above the boiler for superheating, grate surface 217 sq. ft., heating surface 6642 sq. ft., steam pressure 30 lbs., revo. 26

per min., speed 18 miles an hour.

This boat was considered the fastest that had ever gone to China up to that date, and she ran many years from Shang-hae up and down the river.

In 1860 the Long Island Sound freight boat, "City of Norwich," to run between New York and Norwich, Conn., came out. She was 200 ft. long, 36 ft. beam and 12 ft. deep, tonnage 900 tons, draught 6 ft. 9 ins.; she had a single beam engine, built at the Allaire Works, cylinder 54 ins. diam. by 11 ft. stroke, with Sickels' cut-off, the dash pots being central with the valve stems, paddle wheels 31 ft. diam. by 7 ft. 9 ins. face. One flue and tubular boiler, with two tiers of furnaces, on E. W. Smith's patent plan, steam chimney, grate surface 156 sq. ft., heating surface 3003 sq. ft., steam pressure 25 lbs, cut-off at 2 ft. makes 18 revo. per min., and at 3 ft. cut-off makes 20 revo. per min., speed 14 miles an hour.

This vessel was in the Government service on the Chesapeake Bay during the war, and has since been on the Norwich Line.

The "City of New London," a sister boat, was built the year after, and both boats are still running. (1893).

In 1861 the Pacific Mail Steamship Co. brought out their wooden side-wheel steamship "Constitution," built by W. H. Webb; length 360 ft., beam 45 ft., depth

31½ ft., tonnage 3500 tons. She had one beam engine, built at the Novelty Works, New York, cylinder 105 ins. diam. by 12 ft. stroke, Allen & Wells' cut-off gear, paddle wheels 40 ft. diam. by 12 ft. face; four round flue boilers, and surface condenser.

When this steamer ran on the California route, carrying light merchandise, mails and passengers, she would go from 9 to 10 knots, on 32 tons of coal per day. But when the Central Pacific Railroad was being constructed, and the ships of this class carried heavy loads of railroad iron, the speed fell off to from 7 to 8 knots, and the consumption of coal increased to about 50 tons per day on account of the wheels being so deep in the water.

This Company built about sixteen similar ships, the last one, the "America," came out in May, 1869, and was 380 ft. long, 50 ft. beam, by 31½ ft. deep, tonnage 4100 tons. She had a beam engine, cylinder 105 ins. diam. by 12 ft. stroke, paddle wheels overhung, and 42 ft. diam. by 12 ft. face. When this ship left New York deep, the engine was only making seven revolutions per minute.

During stormy weather on the China Line, these engines would not make more than four to five revolutions per minute, and the engineer had to stand by and help them over the centre with the starting bar.

The "Henry Chauncey," one of these ships which ran on the line from New York to Aspinwall, with a steam cylinder 100 ins. diam. by 12 ft. stroke, cost $750,000, carried 1000 tons freight at a speed of 9½ to 10 knots, consuming 45 tons of coal per day.

In contrast to this, the iron screw steamer, "Panama," built for the Pacific Mail S. S. Co. in 1873, having compound engines, cylinders 30 ins. and 56 ins. diam. by 4½ ft. stroke, cost $250,000 carried the same amount of freight, and the same number of passengers at the same speed, on a consumption of 15 tons of coal per day.

In 1864 the screw steamboats, "Electra" and "Galatea," for the New York and Providence Line, came out. They were 260 ft. long, 40 ft. beam and 15 ft. deep, tonnage 1640 tons, draught 12 ft. The engines were vertical direct-acting, built at the Etna Iron Works New York, with two cylinders 44 ins. diam. by 3 ft. stroke, slide valves, and adjustable cut-off valves on the back of them, propeller 13 ft. diam. by 22 ft. pitch. Two return flue and tubular boilers, with steam chimneys 13 ft. high, grate surface 154 sq. ft., heating surface 6060 sq. ft., steam pressure 26 lbs., revo. 70 per min., speed 15 miles an hour, consumption 20 tons coal from New York to Providence, distance 180 miles.

In 1866 the steamship, "Rising Star," built for the Star Line from New York to New Orleans, came out.

She was 315 ft. long, 44 ft. beam, by 31 ft. deep, tonnage 3500 tons, draught 17 ft.; she had a single beam engine, built at the Etna Iron Works, N. Y., cylinder 100 ins. diam. by 12 ft. stroke, steam jacket, with a separate boiler to supply it with steam at a higher pressure; Sickels' adjustable cut-off gear, surface condenser, paddle wheels 36 ft. diam. by 11½ ft. face, buckets stepped to prevent jarring. Two flue and tubular boilers, with two tiers of furnaces on E. W. Smith's patent plan, and steam chimneys 18 ft. high for superheating, grate surface 435 sq. ft., heating surface 10,672 sq. ft., steam pressure 25 lbs., cut-off at 4 ft., revo. 20 per min., speed 15 knots light. This ship was sold to the Pacific Mail S. S. Co., and ran from New York to Aspinwall.

In 1867 the steamboats, "Bristol" and "Providence," of the Fall River Line, from New York to Boston, came out. They were built by W. H. Webb, and were 360 ft. long, 48 ft. 4 ins. beam, 16 ft. 6 ins. deep, tonnage 3000 tons, draught 10 ft. 3 ins. They had single beam engines, built at the Etna Iron Works, N. Y.; cylinders 110 ins. diam. by 12 ft. stroke, Sickles' adjustable cut-off gear, surface condenser, paddle wheels 38 ft. 8 ins. diam. by 12 ft. face, stepped buckets to prevent jarring and shaking. There were three flue and tubular boilers, with two tiers of furnaces on E. W. Smith's plan, steam chimneys on the two outside boilers

21 ft. high for superheating, grate surface 510 sq. ft., heating surface 13,850 sq. ft., steam pressure 25 lbs., cut-off at 4 ft., revo. 18 per min., average I. H. P. 2750, coal per I. H. P. 2.8 lbs. per hour, speed 19 miles an hour.

These boats excelled in speed, splendor and convenience of acommodation, steadiness of motion, and in economy of fuel, any boats which had ever ran on Long Island Sound up to that date. The "Bristol" was burned accidentally, but the "Providence" is still in service, (1893).

In 1873 the American Steamship Co. completed their steamer, "Pennsylvania," and she commenced running from Philadelphia to Liverpool in May of that year. This ship was built by W. Cramp & Sons, Phila., and is 355 ft. long, 43 ft. beam, and 33½ ft. deep, tonnage 3030 tons. The engines were compound and surface condensing, with the cranks set at right angles, cylinders 57 ins. and 90 ins. diam. by 4 ft. stroke; the main slide valves are on the outsides of the high and low-pressure cylinders, and each is fitted with a cut-off valve on the back, steam jacket on the high-pressure cylinder only; propeller four bladed, 17 ft. diam. by 24 ft. pitch. There were three double-ended cylindrical boilers with six furnaces in each, grate surface 272 sq. ft., heating surface about 7800 sq. ft., steam pressure

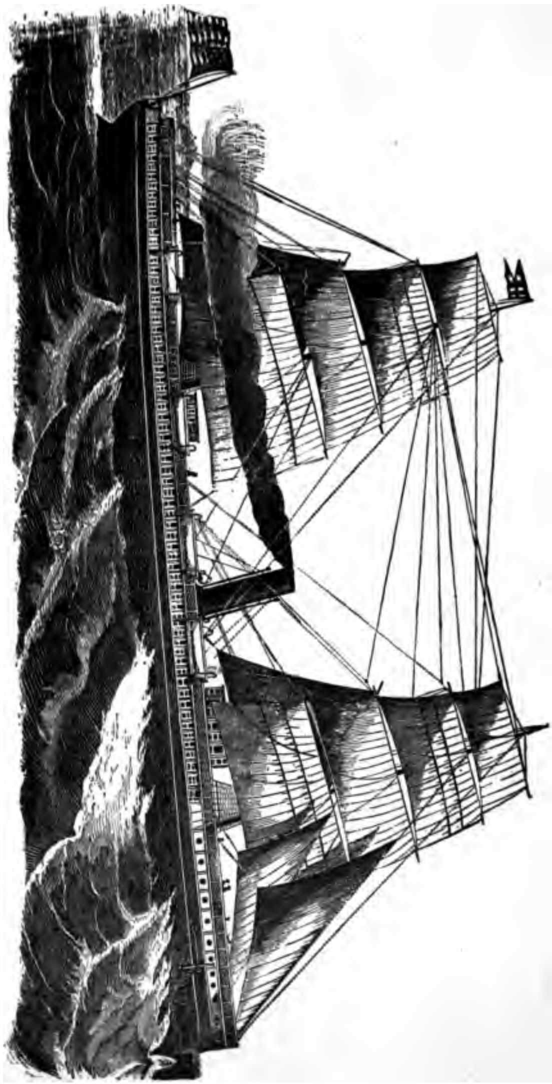
60 lbs., cut-off at 19 ins. in the high-pressure cylinder, revo. 60 per min., average speed 12.8 knots, consumption 44 tons of coal per day, coal per horse per hour 2 lbs., indicated H. P. 2000.

The sister ships, "Ohio" and "Indiana," were added to this Line the same year, and the "Illinois" in January, 1874.

In 1887 the "Ohio" was fitted with triple expansion engines by J. Howden & Co., Glasgow, cylinders 31 ins., 46 ins. and 72 ins. diam., by 4 ft. 3 ins. stroke, and three single-ended tubular boilers to carry 160 lbs. steam, and with Howden's forced hot-blast, grate surface 112 sq. ft. After a four hours trial, it was found that the indicated horse power was 2124, the consumption was reduced to 28 tons coal per day, and per horse power per hour to 1.23 lbs., and the cargo space was increased 740 tons. The other ships were afterwards similarly changed.

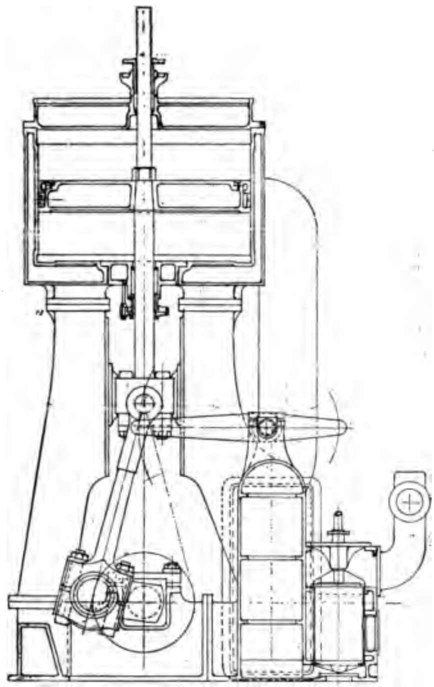
In 1873 the Pacific Mail S S. Co. completed their three iron steamships, "Colon," "Acapulco" and "Granada." The first was built at Chester, Pa., and the two latter at Wilmington, Del.

The compound engines were built by the Elder Co., Glasgow, and fitted on board the vessels in New York. They were 300 ft. long, 40 ft. beam and 30½ ft. deep, tonnage 2686 tons, draught 18 ft., cylinders 50 ins. and



"S. S. COLIMA."

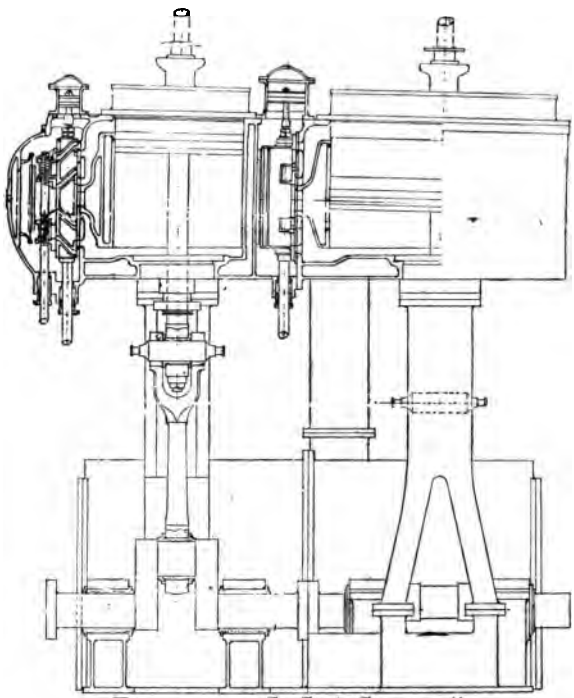
86 ins diam. by 3 ft. 6 ins. stroke, slide valves with cut-off valve on the high-pressure cylinder, steam jackets on both cylinders, surface condenser. There were four



ENGINES OF S. S. "COLIMA."

single-ended cylindrical tubular boilers, with a super-heater common to all, grate surface 228 sq. ft., heating surface 6690 sq. ft., steam pressure 60 lbs., propeller 16

ft. 3 ins. diam. by 24 ft. pitch, indicated H. P. 1330, consumption per day 30 tons coal, per horse power per hour 2.1 lbs., average speed 11 knots.



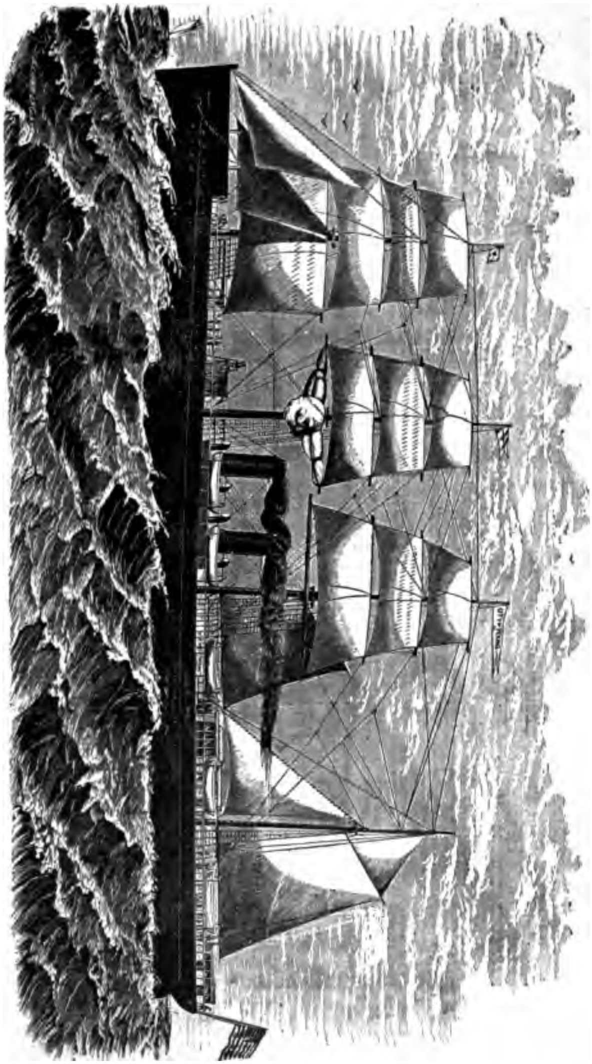
ENGINES OF S. S. "COLIMA."

These ships carried 2000 tons freight, or twice the amount carried by the paddle wheel steamer, "Henry Chauncey," on the same coal consumption, and two

knots per hour faster, and cost about one-half the price of the "Chauncey."

The same year, 1873, the Pacific Mail S. S. Co., completed the "Colima," built by J. Roach at Chester. She was 312 ft. long, 40 ft. beam, 30½ ft. deep, tonnage 2906 tons, draught 18 ft. The engines were compound, designed by T. Main, cylinders 51 ins. and 88 ins. diam. by 3½ ft. stroke. In other respects the ship was the same as the "Colon."

In 1874 the Pacific Mail S. S. Co. completed their iron screw steamships, "City of Panama" and "Guatemala," built by J. Roach at Chester, Pa. They were 258 ft. long, 36 ft. beam, 20 ft. 4 ins. deep, tonnage 1500 tons, draught 14 ft. The engines were of the compound type, designed by T. Main, cylinders 30 ins. and 56 ins. diam. by 4½ ft. stroke, slide valves with a cut-off valve on the high-pressure cylinder, steam jackets on both cylinders; the high-pressure cylinder has a liner with a flange on the bottom end, which forms the jacket, surface condenser; there were four single-ended two-furnace boilers, with one superheater common to all, grate surface 144 sq. ft., heating surface 3772 sq. ft., steam pressure 80 lbs., propeller 13 ft. diam. by 21 ft. pitch, four blades; indicated horse-power 700, coal per day 15 tons, coal per indicated horse-power per hour 2 lbs., speed 10 knots.



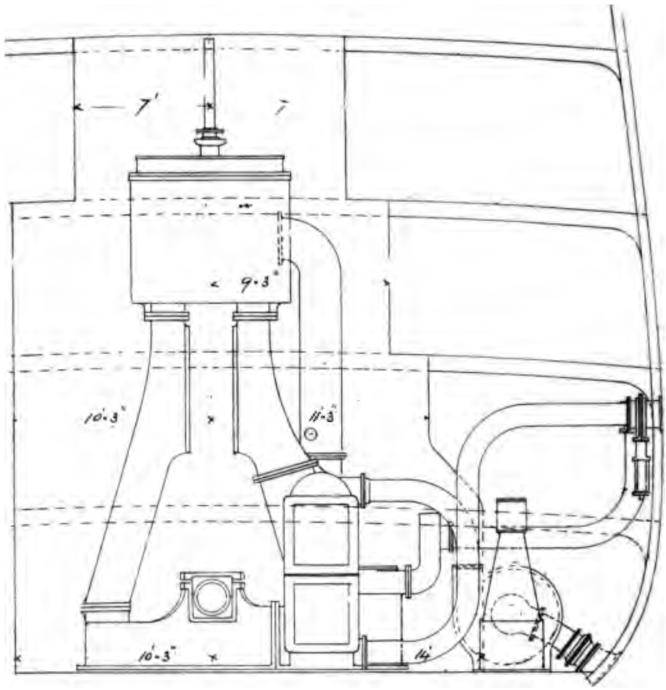
S. S. "City of Peking,"

In 1874 The Pacific Mail S. S. Co. completed their steamships, "City of Peking" and "City of Tokio." They were built by John Roach at Chester, Pa., and were 423 ft. long, 47 ft. 10 ins. beam, and 38½ ft. deep, tonnage 5000 tons, draught 22 ft. They had two pairs of vertical compound engines, designed by T. Main, cylinders two 51 ins. and two 88 ins. diam. by 4½ ft. stroke, and steam jacketed on the sides, bottoms and tops; the high-pressure cylinder had a liner bolted with a flange at the bottom, and packed at the top, and this liner formed the steam jacket; on the low-pressure cylinder the jacket was cast on; the slide valves were double-ported, with a cut-off valve on the back for the high-pressure cylinder, and a ring to relieve the pressure, surface condenser. There were ten single-ended boilers with three furnaces in each, arranged in two groups, with two smoke pipes, two superheaters, grate surface 570 sq. ft., heating surface 17,850 sq. ft., propeller 20 ft. 3 ins. diam. by 29 ft. pitch, four blades; indicated average horse-power 3500, consumption 75 tons coal per day, revo. 52 per min., steam pressure 60 lbs., speed 15 knots, coal per I. H. P. per hour 2 lbs.

When running from San Francisco to Hong Kong, using five boilers and consuming 50 tons of coal per day, the speed was about 11 knots; the indicated horse-power was 2500, and the coal per horse-power per hour was

1.8 lbs. The "Tokio" was wrecked at Yokohama, but the "Peking" is still running, (1893).

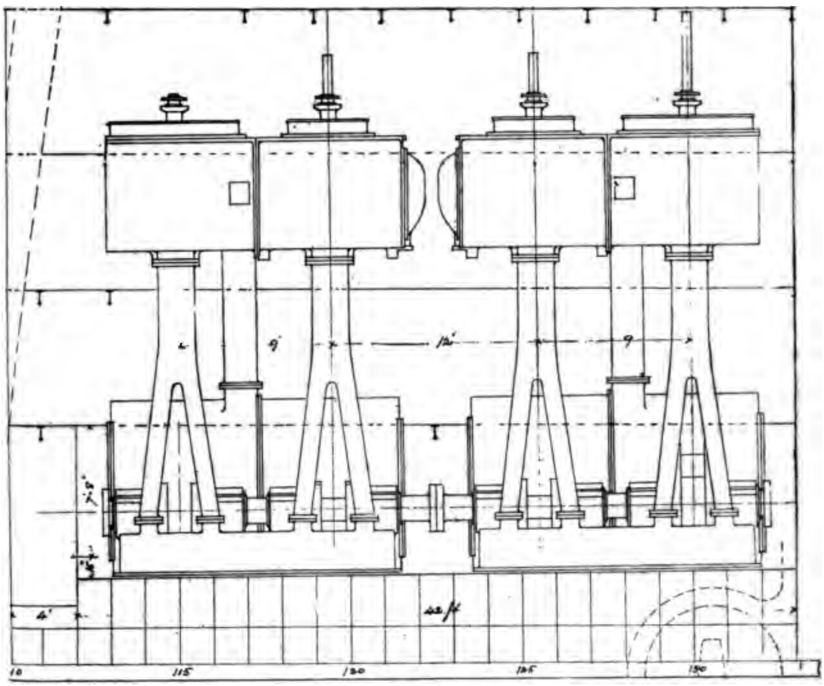
In 1875 The Pacific Mail S. S. Co. completed their



ENGINES OF S. S. "CITY OF PEKING."

steamships, "City of San Francisco," "City of New York" and "City of Sydney." They were built by J. Roach at Chester, Pa., and were 352 ft. long, 40 ft.

beam, 28 ft. 10 ins. deep, tonnage 3000 tons, draught 21 ft. They had compound engines, designed by T. Main, cylinders 51 ins. and 88 ins. diam. by 5 ft. stroke



ENGINES OF S. S. "CITY OF PEKING."

and jacketed on the sides, bottoms and tops; short slide valves, and cut-off valves on the back for both cylinders, surface condenser. There were six single-ended return

tubular boilers with three furnaces in each, and one superheater, grate surface 378 sq. ft., heating surface 10,650 sq. ft., propeller 20 ft. diam. by 23½ ft. pitch, four blades, average indicated horse-power 1800, revo. 52 per min., consumption 36 tons coal per day, coal per I. H. P. per hour 1.86 lbs., steam pressure 80 lbs., speed 13 knots.

In 1879 the "Chalmette," belonging to the Morgan Line, between New York and New Orleans, was completed. She was built by Wm. Cramp & Sons, Philadelphia, and was 322 ft. long, 42 ft. beam, and 21 ft. 3 ins. deep, tonnage 2983 tons. The engine was of the single tandem type, with one connecting rod and one crank, two cylinders 35 ins. and 70 ins. diam. by 4½ ft. stroke. Four single-ended boilers with three furnaces in each, steam pressure 85 lbs., average I. H. P. 1350, consumption 32 tons coal per day, coal per I. H. P. per hour 2.2 lbs.

The "Excelsior" was added to this Line in 1882, and the "El Dorado," and "El Paso" in 1884; they had tandem engines, cylinders 38 ins. and 76 ins. diam. by 4½ stroke.

The "El Mar" was added in 1889, with triple expansion engines, cylinders 29 ins., 45 ins. and 74 ins. diam. by 4½ ft. stroke; and the "El Sol" was added in 1890 to the Line, now owned by the Pacific Improve-

S. S. "El Sol"

ment Co.

The "El Sol" is 391 ft. long, 48 ft. beam and 33 ft 9 ins. deep, with four masts; tonnage 4522 tons; built by W. Cramp & Sons, Philadelphia. Triple-expansion engines, cylinders 32 ins., 52 ins. and 84 ins. diam. by 4½ ft. stroke, surface condenser. Steam of 160 lbs. is supplied by three double-ended boilers with six furnaces in each, speed 15 knots.

Three similar vessels, the "El Sud," "El Norte" and "El Rio," have been added to this line, running from New York to New Orleans in connection with the Southern Pacific Railroad, to California. They were built at Newport News, Va.; the latter vessel has only two masts.

The Newport News Ship-building and Dry Dock Co., (established by C. P. Huntington, President of the Southern Pacific Railroad), are now building the "El Sid," a similar vessel for the same Line.

They are also building two twin screw freight steamers, 10,000 tons, and over 500 ft. long, to ply between New Orleans and Liverpool. It is said that these are to be the nucleus of a fleet of American ocean steamers, fully equal in all respects to the highest achievements of modern marine architecture.

The Red D. liner, "Venezuela," built by W. Cramp & Sons, 1889, was 303 ft. long, 40 ft. beam and 27 ft. 9

ins. deep, tonnage 2843 tons, and has triple-expansion engines; cylinders 25 ins,, 41 ins. and 67 ins. diam., by 3½ ft. stroke; steam of 160 lbs. pressure is supplied by

C. P. HUNTINGTON.

six return tubular boilers, average I. H. P. 2060, coal per day 28.7 tons, coal per I. H. P. per hour 1.3 lbs.

In 1890 the steamships, "Seguranca" and "Vigil-

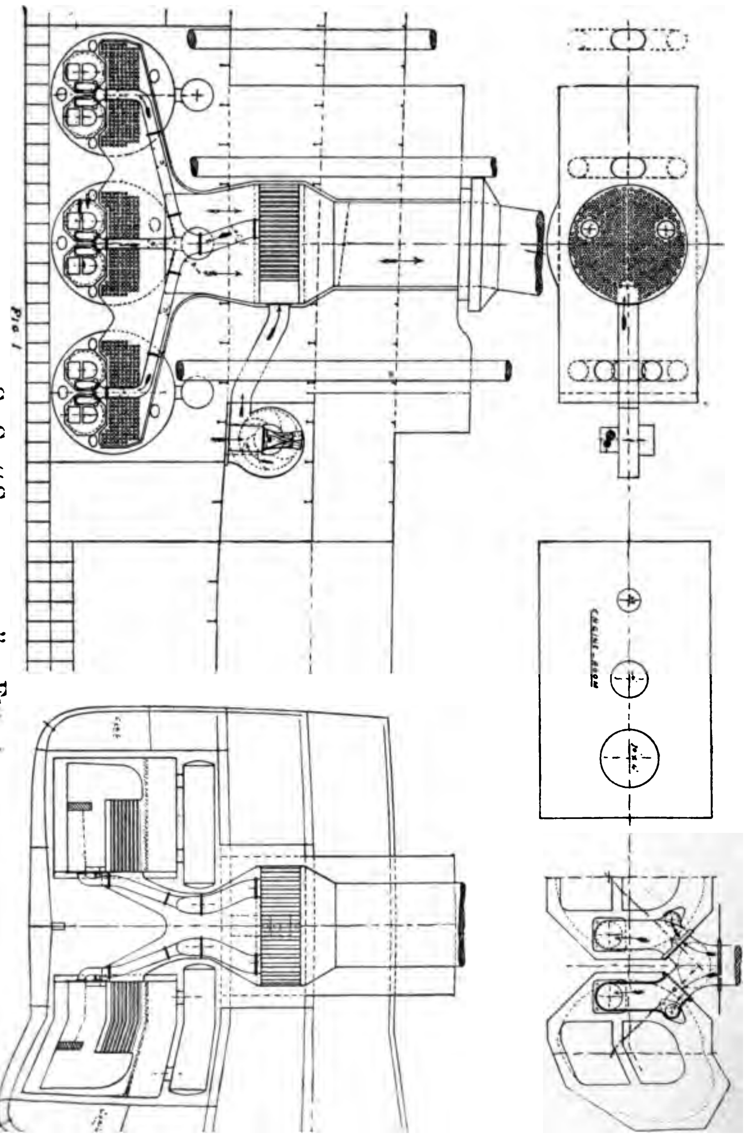
ancia," belonging to the United States and Brazil Mail Steamship Co., were completed.

They were built by the J. Roach Co., at Chester, Pa., and are 320 ft. long, 44 ft., 4 ins. beam, and 28 ft. deep, tonnage 4,050 tons, draught 20 ft. The engines are of the triple-expansion type, cylinders 28 ins., 44 ins., and 70 ins. diam., by 4 ft. stroke; no steam jackets; surface condenser, cut off by the lap on the slide valves, and the reversing links; piston valve on the high-pressure cylinder. There are six cylindrical tubular boilers, with two corrugated furnaces in each, and a horizontal steam-drum to each boiler; grate surface 270 sq. ft., heating surface 9,700 sq. ft. The hot-blast system of T. Main, and the Eureka circulator were fitted to the boilers, steam pressure 180 lbs., indicated horse-power per hour 2,750, consumption, when under way, per day, 38 tons coal, coal per I. H. P. per hour 1.28 lbs., speed at sea 12 knots, revolutions per min. 70.

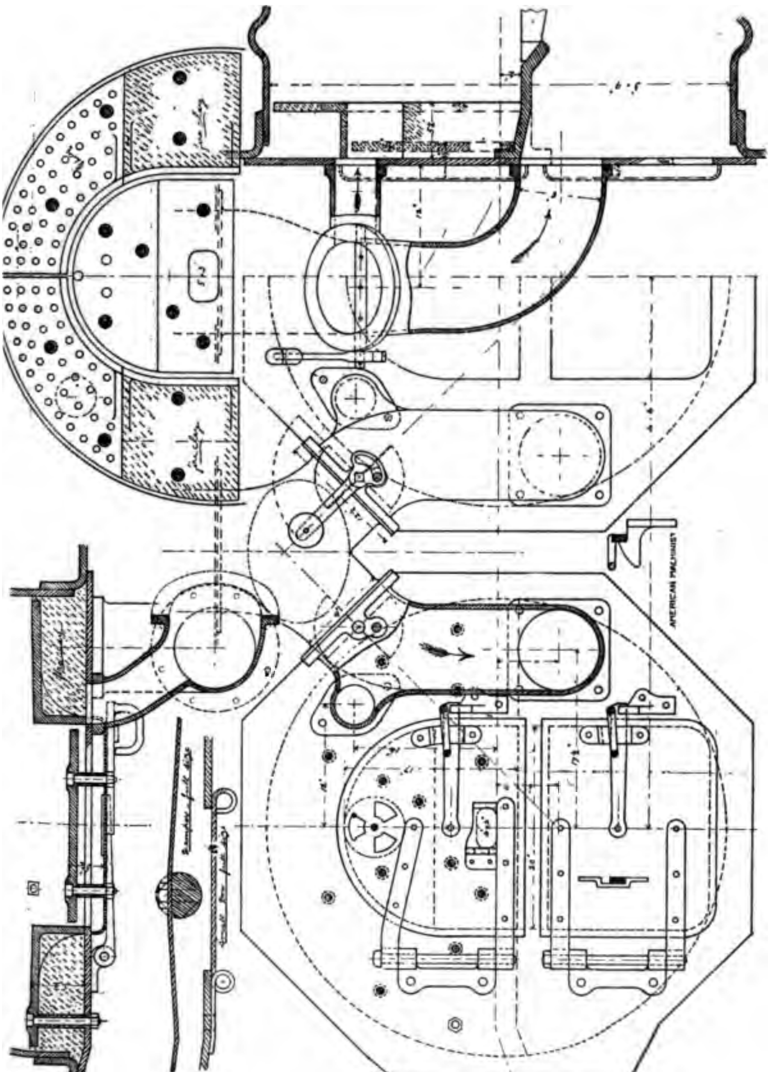
The general arrangement of the hot-blast, slightly modified, in regard to the blower, is shown by fig. I.

The arrangement of the furnace fronts is shown by fig. 2, and the steam fan blower arrangement is shown by fig. 3.

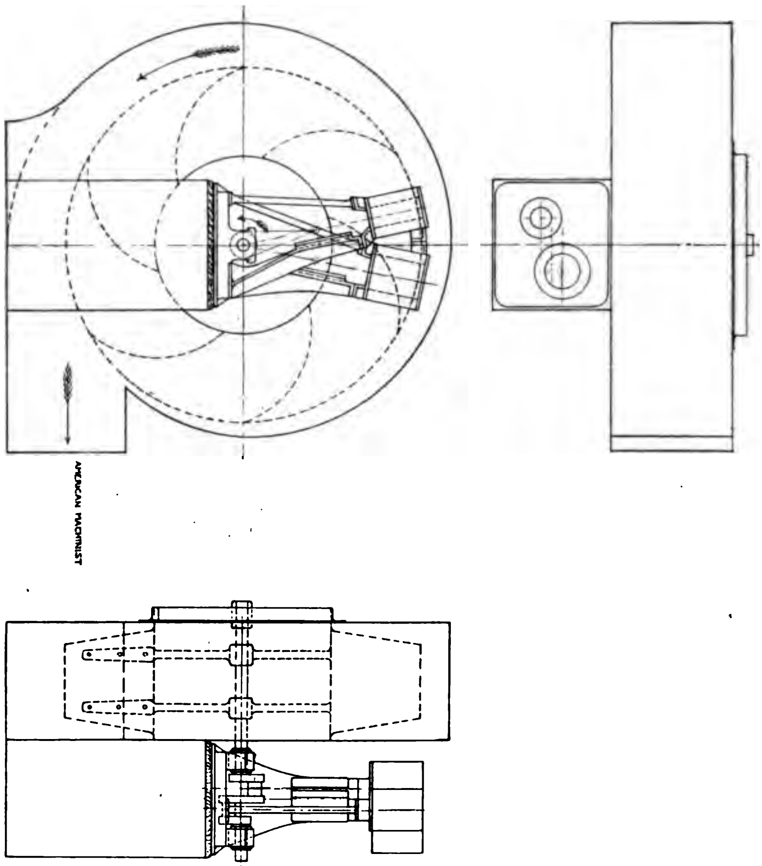
On these ships the pressure blower was used, but it has since been demonstrated, that for moderate blast pressure, the fan blower is equally effective, while it is



S. S. "SEGURANCA." FIG. 1.



S. S. "SEGURANCA." FIG. 2.



S. S. "SEGURANCA." FIG. 3.

not so bulky, nor so costly, and it weighs much less.

The object aimed at in this hot-blast is to control the combustion of the coal in the furnace by means of closed furnaces and artificial blast, without reference to the condition of the atmosphere, the wind, or the height of the smoke pipe or chimney, and also to utilize the heat of the waste furnace gasses, and return it to the furnaces in the air which supports combustion.

It will be observed from the illustration that the waste furnace gasses, and the air to support combustion move in opposite directions, and consequently that while the one decreases in temperature, the other increases. It was found that the temperature of the waste furnace gases below the air heater was 700 degrees, while above the heater it was only 450 degrees. It was also found that the temperature of the air drawn from over the after boilers, and from the engine room was 115 degrees, while it was delivered into the furnaces at a temperatute of 300 degrees. Consequently all the heat necessary to raise the temperate of the air from the fireroom temperature up to 300 degrees was saved.

It will further be observed from fig. 2. that the air is supplied to the ashpit by an eight inch pipe, while a four inch pipe supplies the furnace above the grate. Consequently 80 per cent. of the air goes under the grate, and 20 per cent. above.

It is found that when the furnace is properly manipulated, a very perfect combustion of bituminous coal is obtained, and scarcely any smoke is perceptible.

With this system there is absolutely no danger of causing leaky tnbes. There is a valve to shut off the air before opening the furnace door, and when open there is nearly an atmospheric balance at the door, so that no cold air enters the furnace, and no hot gas comes out. Then there is no difficulty in consuming as much coal on the grate, as may be consistent with producing good combustion at the same time, For it should be remembered that three operations go on in combustion. First, the combustible gas has to be liberated or evolved from the coal; second, the air and combustible gas have to be mixed, and third, combustion of the gas has to be effected before it enters the tubes and becomes reduced below the ignition temperature of about 1000 degrees. And if combustion is too rapid, sufficient time does not elapse to allow these operations to be effected.

The air above the grate is first admitted into the hollow furnace front, then through the perforated front lining into the furnace in fine streams, in order to facilitate the mixing with the combustible gases in the furnace before combustion.

The blower shown on fig. 3 is arranged with curved blades or vanes, as in the Appold pump and Lloyd

blower; it is of large diameter, and driven by Main's patent balanced compound engines.

In 1888–89 the hot-blast system of T. Main was applied to the U. S. and Brazil Mail S. Ship Co's. steamers, "Advance," "Allianca" and "Finance," and when kept in order and properly worked the saving in coal was from 20 to 25 per cent. of the coal used while under way.

The "Advance," on her voyage from Rio Janeiro to New York in June and July, 1888, as per engineer's log, consumed 32 tons of coal per day, and the running time was 21 days 10 hours. And on the voyage from Rio Janeiro to New York in August and September, 1888,—as per log—the first after the hot-blast was fitted, the consumption was 22.5 tons of coal per day, and the running time was 21 days, which shows that the saving by the hot-blast was 30 per cent. of the coal, and 10 hours time on the voyage.

In consequence of the strong competition of the English freight steamers, (or tramps, as commonly called,) together with a change in the management of the Company, and the mutilation and neglect of the coal-saving apparatus on their ships. The U. S. and Brazil S. S. Co. became financially embarrassed, and went into the hands of a Receiver in March, 1893. The five ships were libeled and sold at auction by the United

States Marshal, by order of the Court.

It may be asked why the American steamship does not successfully compete in the foreign trade? Two reasons may be given; first, Congress has refused to give sufficient protection to ships engaged in the foreign trade, so as to compensate for the high rate of wages paid in the United States ports, compared with those paid in foreign ports. Second, the British freight steamer is more cheaply constructed, but particularly, because they are run at less cost, on account of the low rate of wages paid to the crew, and that the British freight ship-owner adopts the fuel saving devices as they come up.

This class of vessels were first introduced for conveying coal from the several sea-bordered coal-yielding districts of England to London, to take the place of the sailing colliers.

Among the first of this new class, were the screw colliers, "Black Prince" and "Fire-Fly," built by T. Vernon & Sons, of Liverpool, for the General Iron Screw Collier Co., and both vessels were fitted with engines by James Watt & Co., of Soho and London.

The "Black Prince" was completed in July, 1854, and on her first voyage made the passage from Liverpool to Cardiff in 31 hours, and from Cardiff to London in 64 hours, with 700 tons of coal on board, distance 690

knots, or 7¼ knots per hour, draught of water loaded 15 ft. The engines had two cylinders 34 ins. diam. by 22 ins. stroke, with jet condenser, tubular boilers, steam abont 16 lbs. pressure, revo. 58 per min., I. H. P. 262, propeller 10 ft. diam. by 16 ft. pitch, consumption 5 to 6 lbs. coal per I. H. P. per hour, and manned the same as the old sailing collier, except as to the engineers crew, which was additional.

And this class of vessel since that day, has continued to grow in number and size, and the machinery has improved in coal economy, through the different stages of surface condenser, superheated steam, higher pressure of steam, compound engines, triple-expansion engines, evaporators, heaters for feed water, and forced hot-blast, until we see in the White Star freight steamship, "Bovic," lately built, a vessel that will carry about 8000 tons of freight at a speed of 13 knots, with twin screws, triple-expansion engines, steam at 180 lbs. pressure, forced hot-blast, and other improvements for running, and handling freight cheaply; consumption about 1.25 lbs. coal per I. H. P. per hour.

And these vessels are to-day seen all over the world competing for business in every country. Late accounts from England report depression in the shipping trade, and exceedingly low and unremunerative freights offered in all parts of the world. Ship-owners there say that it

is consequent on over-production, and a large number of vessels are lying idle in almost all ports, chiefly those having compound engines, as they cannot compete with ships having triple-expansion engines, and hot-blast, which use a small amount of cheap coal.

Within the last six years, it is reported that 549,000 tons of British steamers, and 428,000 tons of sailing ships, have been sold to foreigners, principally to Norway, France and Germany; and these ships are now competing with both British and American ships.

In the case of the Brazil trade, it has been the custom to send freight steamers from Liverpool to Rio Janeiro with a general cargo, from there to New York with coffee, or from Para to New York with rubber, and then from New York to Liverpool with a general cargo, and so making a triangular voyage. The same is largely done by French and German freight steamers from their home ports. And this is the state of things which the U. S. and Brazil Mail S. S. Co. have been contending against.

The U. S. Government compelled them to carry and handle the mails for the postage money, said to have been less than the service cost, and but for the fact that the Brazil Government paid the Company about $100,000 per annum, for carrying their mails to the United States, the Company would probably have been inslo-

vent before.

On account of the high rate of wages prevailing in the United States, it seems to be necessary that in addition to having their ships fitted with the most economical machinery, there should be some protection or discrimination of some kind in the U. S. ship-owners favor afforded by Congress, in order to give a fair field for competition.

The British are now suffering in this way from the competition of cheaply manned foreign ships; chiefly from the Norwegian ships, which were bought from the British ship-owners.

The steamship, "Kimberly," built at Port Glasgow, and which had been wrecked on the United States coast, was purchased by the Pacific Improvement Co., and reconstructed at Newport News, Va., in 1890. The hot-blast system of T. Main, and the Eureka Circulator were fitted to the boilers at the same time.

The "Kimberly," now called the "San Benito," is 350 ft. long, 41 ft. beam, and 33½ ft. deep, tonnage 3789 tons. The engines are vertical compound, cylinders 44 ins., and 82 ins. diam. by 4½ ft. stroke. There were two double-ended boilers with six furnaces in each, grate surface 228 sq. ft., steam pressure 80 lbs.

The "San Benito," loaded at Norfolk for Liverpool, and left Oct. 20th, 1890, thence to London, Cardiff and

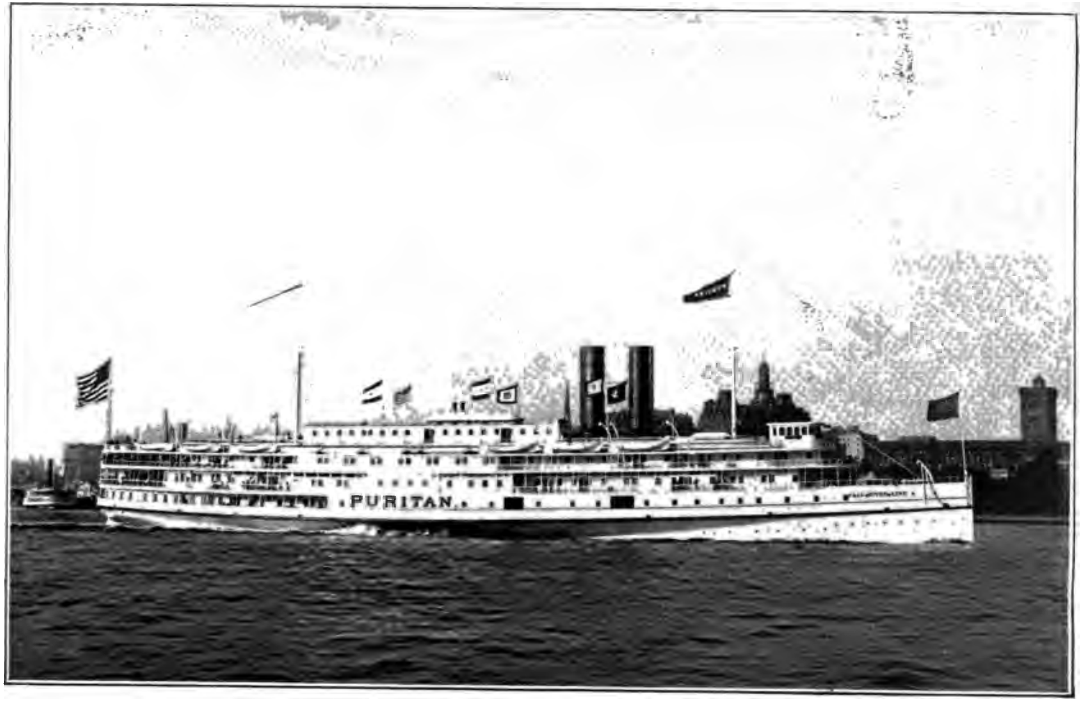
San Francisco; speed 10 knots, coal per day 24 tons, average I. H. P. 1600, coal per I. H. P. per hour 1.4 lbs.

The log of the vessel, before the alteration, showed a speed of 9.6 knots, and a consumption of 34 tons coal per day, which shows a saving of coal of about 30 per cent., and an increase in speed. This ship is now in service as a steam Collier between San Francisco and Vancouver Island.

The Fall River iron steamboat, "Pilgrim," built by J. Roach, at Chester, Pa., came out in 1883. She is 390 ft. long, 50 ft. beam, and 18¾ ft. deep, tonnage 3500 tons. Single beam engine, cylinder 110 ins. diam. by 14 ft. stroke, surface condenser, steam pressure 50 lbs. There are four Redfield boilers, with two steam chimneys and smoke pipes, paddle wheels 41 ft. diam. by about 13 ft. face.

This vessel had a double botton, and many water-tight compartments, which kept her afloat when she struck the rocks near Blackwell's Island New York harbor, making a large hole in the bottom. She was placed safely on the dry-dock and repaired; speed about 18 miles an hour, coal per horse-power about 3 lbs. per hour.

The "Puritan" of the Fall River Line, from N. Y. to Boston, came out in 1888. She was built of steel, with a double bottom and compartments like the "Pil-



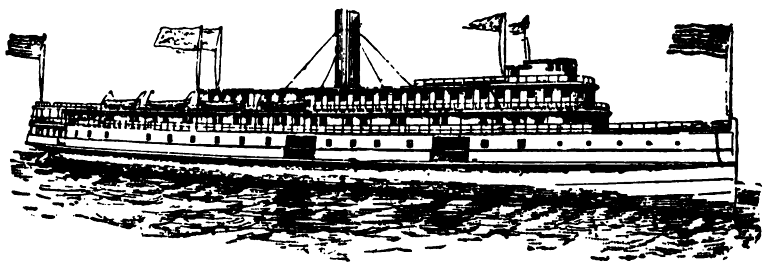
Steamboat "Puritan"

grim," and had a compound beam engine, built by the W. & A. Fletcher Co., New York. The hull was built at Chester, Pa., and is 420 ft. long, 52 ft. beam, and 21 ft. deep, tonnage 4600 tons. The cylinders are 75 ins. diam. and 9 ft. stroke for the high pressure, and 110 ins. diam. and 14 ft. stroke for the low pressure, cut-off on both cylinders, paddle wheels 35 ft. diam. by 14 ft. face. The buckets are feathering, surface condenser. The boilers are of the Redfield return tubular type, for a pressure of 110 lbs., grate surface 850 sq. ft., heating surface 26,000 sq. ft., I. H. P. 7500, coal per I. H. P. per hour about 2 lbs., speed about 19 miles an hour.

The "Plymouth," of the Fall River Line, came out in 1890. She was also built of steel with a double bottom and compartments like the "Pilgrim" and "Puritan." The hull was built at Chester, Pa., and is 366 ft. long, 50 ft. beam, and 21 ft. deep, tonnage 3770 tons. The engines were built by the W. & A. Fletcher Co., New York, and are inclined triple-expansion engines, cylinders 47 ins., 75 ins., and two 81½ ins. diam., low pressure, by 8 ft. 3 ins. stroke; there are two cranks at right angles, the high and one low-pressure engine connect on one crank, and the intermediate and one low-pressure engine connect on the other crank, poppet valves, adjustable cut-off on the high-pressure cylinder, and fixed cut-off on the others, surface condenser, pad-

dle wheels 30 ft. diam. by 14 ft. face; the buckets are feathering. There are eight cylindrical Scotch boilers, fitted for 170 lbs. pressure; each boiler has two corrugated furnaces; I. H. P. 5500, coal per I. H. P. per hour about 1.8 lbs., speed about 19 miles an hour.

In 1892 the steel screw steamboat, "Maine," built by the Harlan & Hollingsworth Co., Delaware, for the New York, Stonington & Providence Line, came out. She



STEAMBOAT "MAINE."

is 310 ft. long, 44 ft. beam, and 17½ ft. deep, tonnage 1703 tons, draught 12½ ft. The engines are direct-acting, surface condensing, triple expansion, with four cylinders 28 ins., 45 ins., and two low pressure 51 ins. diam. by 3½ ft. stroke, propellers four bladed 13½ ft diam. There are four cylindrical return tubular boilers, each has three corrugated furnaces, for a pressure of 160 lbs., grate surface 274 sq. ft., blowers and air-tight

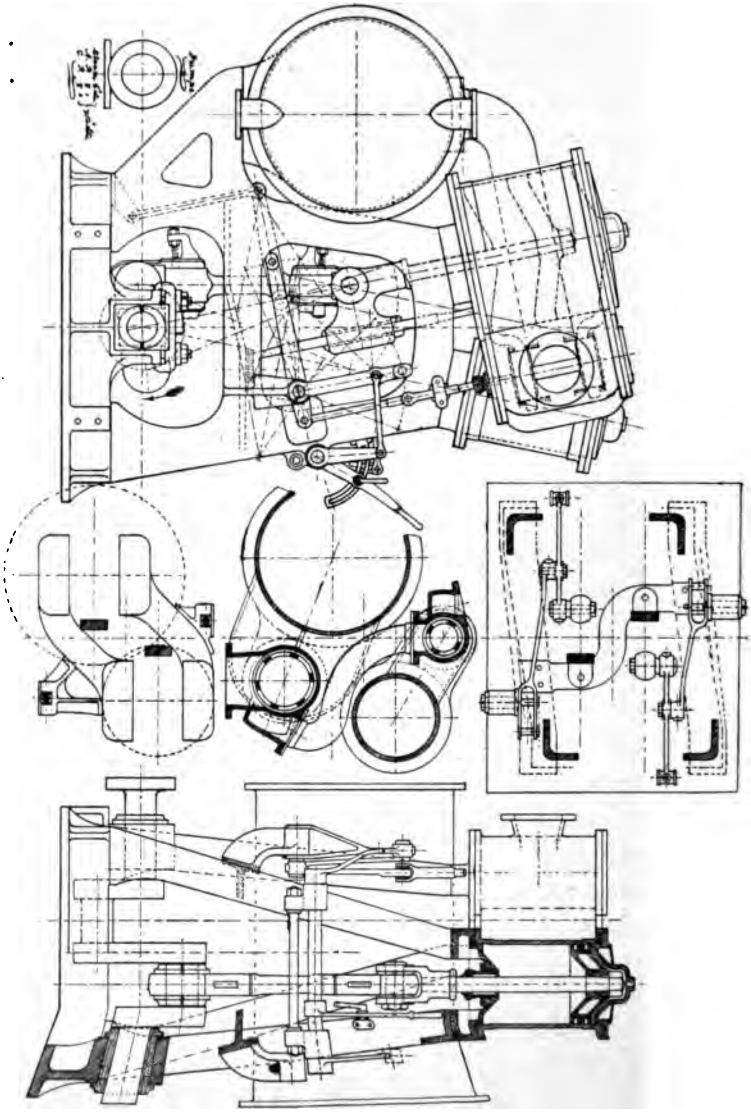
fireroom arranged for forced draft if needed, coal per I. H. P. per hour about 1.6 lbs., speed 18½ miles an hour.

The "New Hampshire" is a sister boat to the "Maine," and both are running successfully, (1893).

The steel steam yacht, "Neaira," was built in 1887 by Houston & Woodbridge of Marcus Hook, Pa., (on the Delaware River), for Lovejoy & Noyes of New York, and is 110 ft. long on the water line, 20 ft. beam, and 10 ft. deep, with 7 ft. 3 ins. draft of water aft, mean draft 5 ft. 10 ins., speed 13.6 knots an hour. The engines of the "Neaira" are of the balanced compound type, were designed and patented by T. Main of New York, and constructed by R. Wetherill & Co., of Chester, Pa.

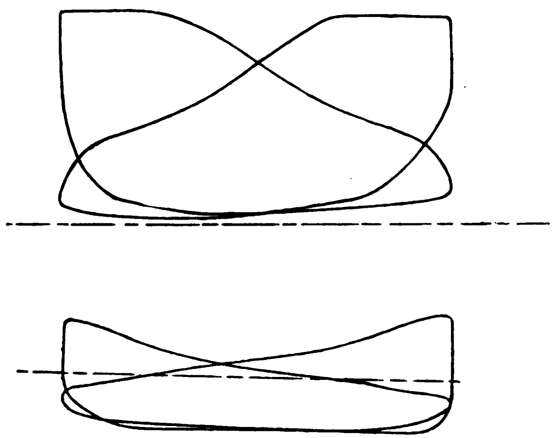
They are illustrated by Fig. 1; the high-pressure cylinder is 15 ins. diam., and the low-pressure is 28 ins. diam. by 16 ins. stroke, the cylinders are placed at an angle of about 23° apart, and the cranks are directly opposite, so that the working parts of the one engine, balance the similar parts of the other, and they work in opposite directions; consequently the pressure of the one piston is balanced by that of the other, through the crank, and the pressure is removed from the shaft journals, except what is due to the weight of the moving parts.

This causes a great reduction of friction in passing



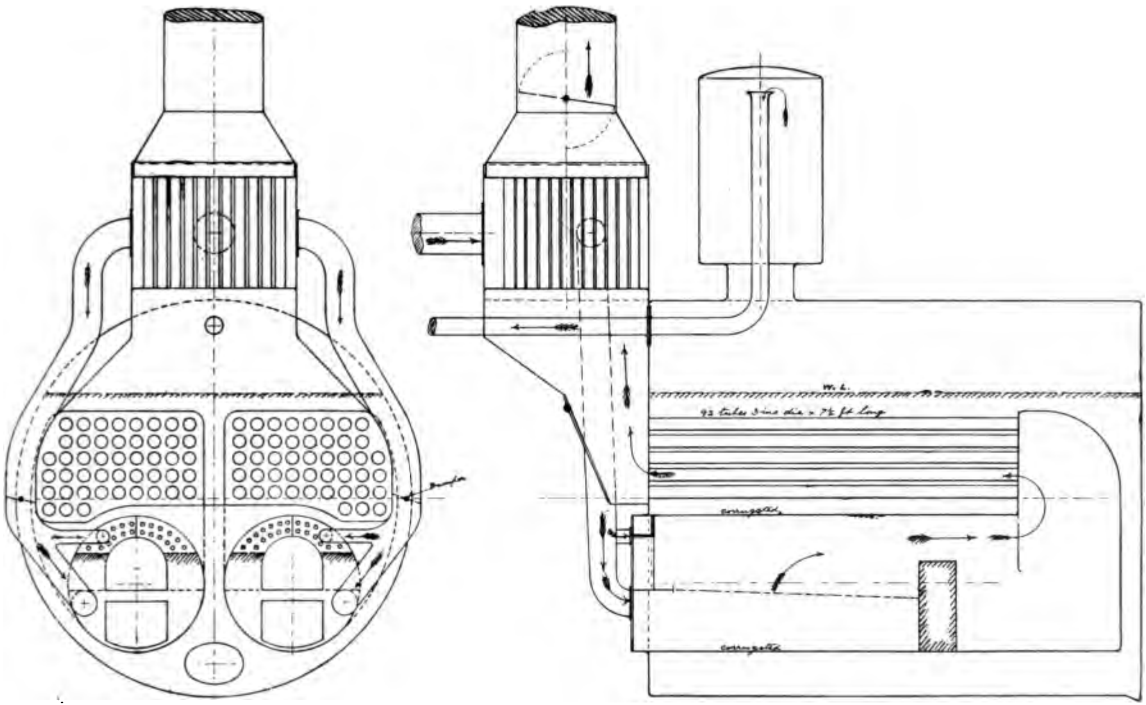
STEAM YACHT "NEAIRA" ENGINES. FIG. 1.

the centres, and consequent increase of power. These engines require only two journals, which makes a great reduction of length in a fore and aft direction, and which in this vessel allowed for an additional row of state rooms athwart ship, which was a very great advantage to the owners. The valve motion is taken from the con-



INDICATOR CARDS OF THE "NEAIRA."

necting rods, and piston valves are used on both cylinders, which are controlled by one starting handle, for starting, stopping, going ahead, backing or working expansively; and owing to the engines being at an angle to each other they have no dead centres, but can be controlled under all conditions.

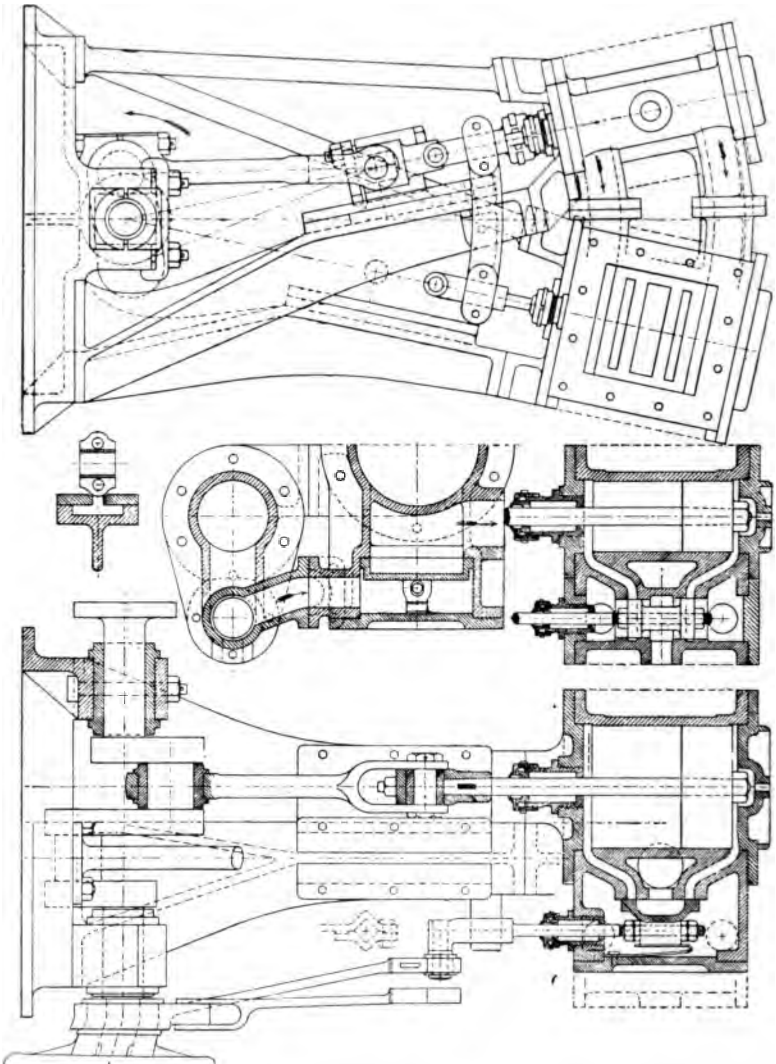


"BOILERS OF THE NEAIRA." FIG. 2

The surface condenser is located on one side of the engines with independent air, and circulating pumps under it. The feed pump is also independent. The thrust bearing is bolted to the bedplate, and accessible in the engine room. In this type of engines the journals require less wearing surface than usual, and tend to remain cool when running fast, owing to the work on them being light.

It is believed that there is no type of engines before the public to-day so compact as these, or which admits of so much power being located in so small a space. Steam is supplied at a pressure of 125 to 150 lbs. by a Scotch type of boiler, (illustrated by Fig. 2), with two corrugated furnaces 33 ins. diam.; the boiler is 8 ft. diam. by 10 ft. long, has a steam drum, and an air heater located at the base of the smoke pipe. T. Main's patent system of hot-blast is fitted to the boiler. A fan blower driven by a pair of balanced compound engines 3½ ins. and 6 ins. diam., by 4½ ins. stroke, is used to draw air from over the boiler, and forcing it through the air heater into the closed furnaces; 80 per cent. of this air goes under the grate, and 20 per cent. of it above, at a temperature of 220°.

This vessel has run several times from New York to New London, a distance of 110 statue miles, in 7 hours, consuming 2 tons of coal during the run.



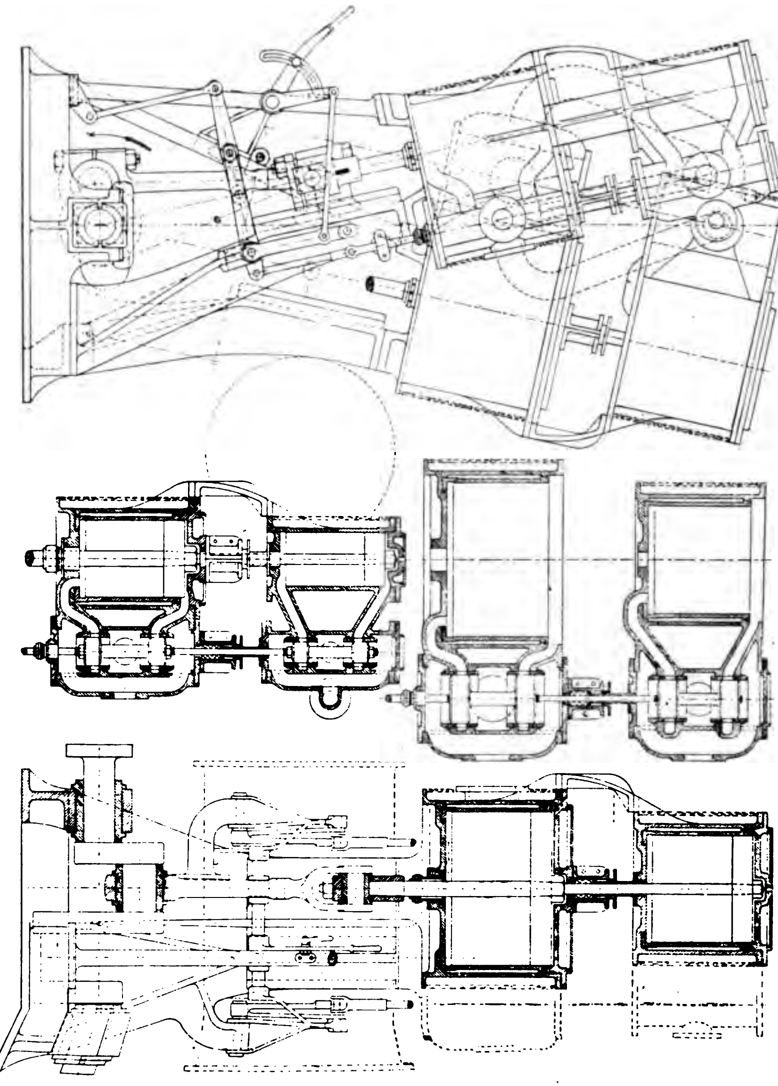
YACHT ENGINES. FIG. 3.

The engines have run at a maximum speed of 180 revolutions per min. with 150 lbs. steam, and 348 indicated horse-power.

They have been used during six yachting seasons, very little has been done to them, and they are now in good condition, (1893).

A modified plan of the blowing engines on this yacht is illustrated by Fig. 3, adapting them for use on small yachts or launches, for running dynamos, blowers, or for stationery work.

When it is an object, in addition to compactness, to attain a high degree of economy of fuel, (and it always is or should be). These balanced engines can be arranged as quadruple expansion engines, fitted with steam jackets, to use steam of 200 to 250 lbs. pressure, supplied from water-tube boilers, of such a type as the Belville, Almy, Roberts, Ward, or similar boilers, fitted on the hot blast system, and such a combination will produce an indicated horse-power on about one pound of coal, when properly carried out and worked; Fig. 4, represents the engines of the "Neaira," modified as balanced quadruple tandem engines, fitted with steam jackets on three cylinders, and so arranged with moveable stuffing boxes that the lower pistons, cylinder heads, and valves, can be removed without disturbing the upper cylinders, and all this will occupy no more space



BALANCED QUADRUPLE TANDEM ENGINES. FIG. 4.

than an ordinary single upright engine.

The steel steam yacht, "Restless," built in 1887 by Houston & Woodbridge, for W. M. Singerly of Philadelphia, was 100 ft. long, 16 ft. beam, and 9 ft. 6 ins. deep.

The engines of the "Restless" are also of the balanced compound type, designed and patented by T. Main, and constructed by R. Wetherell & Co.; they have cylinders 13 and 24 ins. diam., by 16 ins. stroke, similar to those on the "Neaira," and have been used for six yachting seasons with good success.

When engines of this type are on a large scale they may be arranged with two sets of cranks at right angles, the high pressure and first inermediate connected to the forward cranks, and the second intermediate and low pressure pistons connected to the after cranks.

As an example of the progress of steam ships on the Great Lakes, the two twin screw steel vessels now building at Cleveland, O., for the Great Northern Railway, and Northern Steamship Co., may be given. They are intended to run from Buffalo to Duluth in connection with the Great Northern Railway from Duluth to Everett on Pugent Sound.

The ships are being built by the Globe Iron Works Co., Cleveland, and are 380 ft. long over all, 44 ft. beam, and 34 ft. deep; they will cost $550,000 each, and will

have a speed of 20 miles an hour. They will be fitted with two sets of quadruple expansion engines, with cylinders 25 ins., 36 ins., 51½ ins., and 74 ins. diam., by 42 ins. stroke, to develop 7000 I. H. P. The boiler power will consist of a battery of twenty-eight Belleville boilers to carry 225 lbs. of steam, piston valves and Joy valve gear; independent air pumps, and condenser, twin screws, each 13 ft. diam. by 18 ft. pitch.

It is expected that the distance of 1000 miles will be run in 50 hours, and that the outcome of the present contract will be six vessels to form a daily line. The Great Northern already has a fleet of six large steel freight steamers, which have been running from Buffalo to West Superior for the past four years.

There is now a large fleet of steel screw freight steamers, with compound and triple-expansion engines, on the Lakes, engaged in transporting ores, grain, and other merchandise, besides a number of twin screw passenger steamers.

The Long Island Sound steamboat, "Richard Peck," furnishes another example of the twin screw passenger and freight boat. She is 300 ft. long on the water line, 316 ft. over all, 48 ft. beam, and 62 ft. over guards. The engines are triple expansion, 4,000 I. H. P., two propellers 10 ft. 6 ins. diam., speed about 18 miles an hour; built by Harlan & Hollingsworth, Wil-

mington, Del. This boat runs between New York and Newhaven, Conn.

The twin screw steamboats, "Monmouth" and "Sandy Hook," which run from New York to Port Monmouth in connection with the railroad to Long Branch, are examples of fast boats; length 270 ft. over all, beam 35 ft., depth 15 ft. 6 ins., tonnage 1440 tons. They have two sets of triple-expansion engines; the cylinders are 19 ins., 39 ins. and 50 ins. diam., by 30 ins. stroke, revo. 165 per min.; four boilers, steam pressure 160 lbs., speed about 18 miles an hour.

The "Monmouth" was built by Cramps, and the "Sandy Hook" by Harlan & Hollingsworth.

The freight steamers, "Cufic," "Runic," "Tauric," "Nomadic," "Naronic," "Bovic," "Civic" and "Gothic" followed the "Majestic" in the White Star Line. Their tonnage is from six to eight thousand tons each, they were built by Harlan & Wolff, have triple-expansion engines, with steam jackets, carry 180 lbs. steam, have Howden's hot-blast, evaporators, and all improvements, speed about 13 knots, and are considered the largest and most economic freight carriers up to date, (1893); the latest have two screws.

It is announced that the White Star Co. are negotiating with Harlan & Wolff, Belfast, to construct for their line, two steamers about 680 ft. long, 68 ft. beam,

with 45,000 I. H. P., and to be propelled by three screws at a speed of 27 knots an hour, so that the run across the Atlantic, from Queenstown to New York, will take 4½ days only.

CHAPTER VI.

About 1853 Congress ordered six frigates to be built at the Navy yards. The "Merrimac," "Niagara," "Wabash," "Roanoke," "Colorado," and "Minnesota," of about 4,500 tons displacement at 24 ft. draught. The "Merrimac" was 300 ft. long over all, and 51.4 ft. beam; the ship was built at Boston, and the engines at West Point Foundry, N. Y. There were two back-acting engines, cylinders 72 ins. diam., by 3 ft. stroke, with the cylinders at the opposides sides of the vessel. The slide valves were worked by a link motion, and there was a separate cut-off valve worked by a separate eccentric, the varying expansion being obtained by a slot in the lever which worked the cut-off valve, and by which the stroke may be lengthened or shortened at pleasure, jet condenser, propeller (Griffith's) 17 ft., 4 ins. diam., by 26 ft., 2 ins. pitch, made to hoist up when

under sail. There were four boilers, with four furnaces in each, speed 8 to 9 knots, speed with both canvas and steam 12 to 13 knots, steam pressure 10 to 12 lbs., consumption at full steam 40 tons per day, bunker capacity 600 tons coal, revolutions 45 per minute.

This vessel was afterwards the celebrated Ram "Merrimac" that fought with the "Monitor" near Newport News, Va.

The "Niagara" was built at the Brooklyn Navy Yard, from plans by George Steers, and the engines were direct-actiug, built by Pease & Murphy, of New York, from plans by C. W. Copeland. There were three cylinders, 72 ins. diam., aud 3 ft. stroke, with flat slide valves, and cut-off valves on the sides of the valve-chests, the cranks were 120° apart. There were four Martin boilers with six furnaces in each, grate surface 448 sq. ft., heating surface 17,900 sq. ft., propeller 18 ft. 3 ins. diam., by 30 ft. pitch, steam pressure 15.5 lbs., speed 10.5 knots, coal per hour 3,980 lbs., coal per I. H. P. per hour 4½ lbs., revolutions 36.6 per minute.

The "Niagara" and the British Ship-of-war "Agamemnon" were used in laying the first Atlantic Cable.

The "Wabash" was built at the Philadelphia Navy Yard, and the engines were built by Merrick & Towne, of Philadelphia, and had the first flat valve in the navy, with the cut-off valves on the back, adjusted by right

and left screw on the valve-stem, and a balancing ring on the back.

The "Roanoke" and "Colorado" were built at the Norfolk Navy Yard, Va., and the engines at the Tredegar Iron Works, Richmond, Va. They were trunk engines, similar to those built by Penn, of London, for the "Himalaya" troop ship, and many others.

The "Minnesota" was built at the Washington Navy Yard. The engines were on the trunk plan, similar to those of the "Roanoke," and were built at the Washington Navy Yard, under the superintendence of D. B. Martin, Engineer-in-Chief U. S. Navy.

The enormous expense incurred in keeping these frigates in commission, caused them to be gradually withdrawn and replaced by smaller vessels.

Accordingly in 1856–57 Congress ordered the building of five steam corvettes. The "Lancaster," "Hartford," "Brooklyn," "Richmond," and "Pensacola."

The "Lancaster" was built at Philadelphia, tonnage 2,360 tons. The machinery consisted of two back-acting horizontal engines, with cylinders 60 ins. diam. by 30 ins. stroke. Two Martin's vertical tubular boilers, propeller 12 ft. diam. by 19 ft. pitch, speed 9 to 10 knots an hour.

The "Hartford," Admiral Farragut's flagship at Mobile, was built at Boston, and was 264 ft. long over all,

44 ft. beam, draught loaded 16 ft., tonnage 1990 tons. She had two horizontal engines, cylinders 62 ins. diam.

ADMIRAL FARRAGUT.

by 34 ins. stroke, propeller 14 ft. 6 ins. diam. by 24 ft. pitch, made to hoist up out of water. Two Martin's vertical tubular boilers.

The "Brooklyn" was built by J. Westervelt, of New York, and was 247 ft. long, 43 ft. beam, and 22½ ft. deep. tonnage 2000 tons. The engines were built by Pease & Murphy, of New York, and were direct-acting horizontal, the two cylinders were 61 ins. diam. by 33 ins. stroke, with flat slide valves on the upper side, and had adjustable cut-off valves on the back, on the Myers or Bourne plan, with right and left screws for adjustment, jet condenser. She had two Martin boilers, with brass tubes, propeller 14 ft. 6 ins. diam. by 26 ft. pitch, speed 10 knots an hour.

The "Richmond" was built at Norfolk, Va., and was 259 ft. long, 42 ft. beam, draught 16 ft., tonnage 1934 tons; two horizontal engines, cylinders 58 ins. diam. by 30 ins. stroke; two Martin boilers, propeller 14 ft. diam., Sickels' valve arrangement.

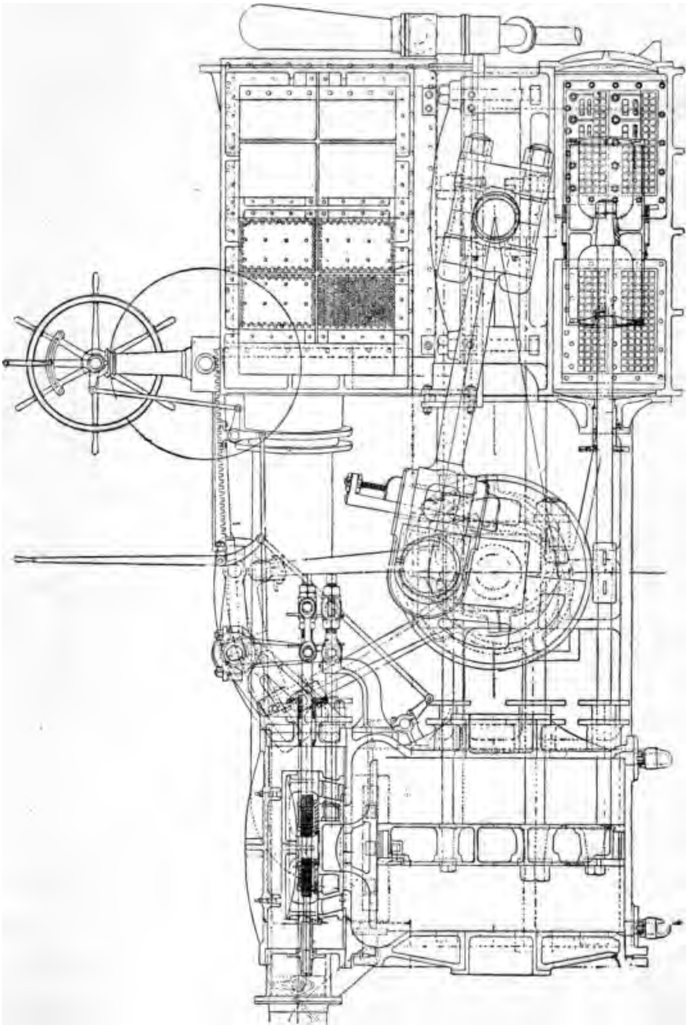
The "Pensacola" was built at Pensacola, Florida, and was 231 ft. long, 44 ft. beam, 21 ft. deep, draught 17 ft. tonnage 2158 tons. The engines were horizontal, had four cylinders about 60 ins. diam. by 3 ft. stroke, with single poppet valves, and cut-off gear; Bodmer compensating balanced cranks, one set at right angles to the other, the pistons worked in opposite directions, two on one set of cranks and two on the other set; these engines were constructed in the Washington Navy Yard under the supervision of Dickerson & Sickels; there was

some delay in finishing them, but when tried they worked well, and the ship made a speed of 13 knots, but as a controversy arose between the designers and the Engineer corps of the Navy, the engines never seem to have got justice done to them; they were finally removed, and a pair of 60 ins. by 3 ft. stroke engines substituted.

In 1857–58 Congress ordered the building of seven steam sloops of war or gun-boats: the "Iroquois," "Wyoming," "Mohican," "Dacotah," "Seminole," "Pawnee," "Narragansett," and the side wheel steamer "Saginaw." The vessels were built at the Navy Yards, and the engines were built from competitive plans furnished by the builders.

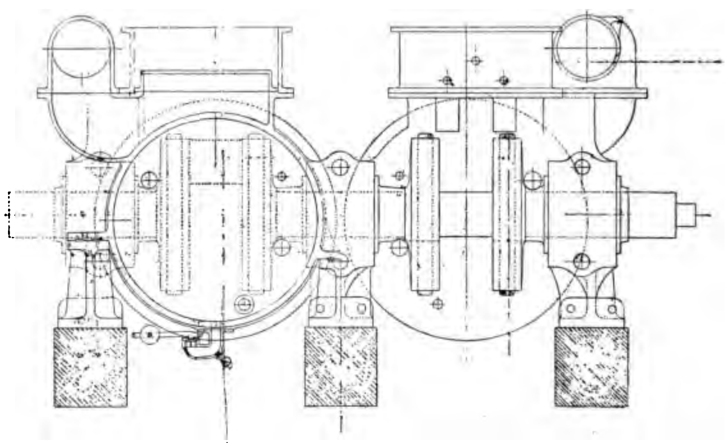
They were the first U. S. Naval vessels in which the surface condenser was introduced. There were sixteen sets of plans presented by the different builders to the Navy Department, for their consideration. The first award, and the highest price, $130,000, was given for the machinery of the "Iroquois." That plan was the most compact, and allowed 230 tons of coal in the bunkers, which was more than the others gave in the space allotted.

This vessel was built at the Brooklyn Navy Yard by constructor B. F. Delano, and was 225 ft. long, 34 ft. beam, by 16 ft. deep, tonnage 1016 tons, draught about



"IROQUOIS" ENGINES.

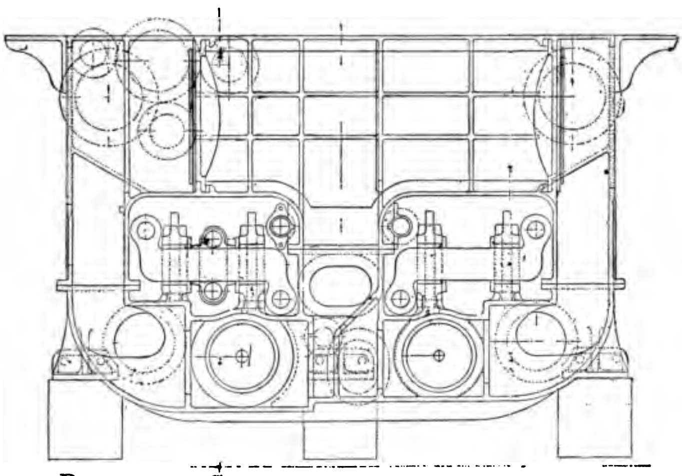
13 ft. The engines were designed by T. Main, and built by Pease & Murphy of New York. They were back-acting horizontal engines, two cylinders 54 ins. diam. by 28 ins. stroke, and counter-balance on the cranks, with Pirisson's double vacuum condenser located over the cross-heads, and this is believed to be the first



CYLINDERS OF THE "IROQUOIS."

condenser arranged that way; the flat slide valves were on the upper side of the cylinders, and had cut-off valves on the back, adjusted by a right and left screw on the valve stem, there was a ring on the back of the valve for relieving the pressure. Propeller, two bladed to

hoist up out of the water, was 12 ft. 2 ins. diam. by 19½ ft. pitch. Two Martin vertical tubular boilers, with seven furnaces in each, one of them having one furnace separate to be used as a donkey boiler, or with the others, grate surface 250 sq. ft., heating surface 7,500 sq. ft., steam chimney 2 ft. above the boiler, steam



PUMPS AND CONDENSER OF THE "IROQUOIS."

pressure 30 lbs., maximum revolutions 86 per min., speed 13½ knots, I. H. P. 800, coal per day at full speed 24 tons, coal per I. H. P. 2.8 lbs. per hour, 18 tons of coal per day gave 76 revolutions, and a speed of 11½ to 12 knots, and 12 tons coal per day gave 63 revolutions

and a speed of 9 knots.

The "Iroquois" was built of live oak, and has had a long and successful career. She went in commission in 1859, and is still in commission now, 1893; has been in continuous service almost, except when undergoing repairs. She was said to have been the fastest vessel in the fleet, when running past the forts at the taking of New Orleans during the civil war. This vessel was always fast, owing to the cylinders being large, the cut-off could be lengthened, when the boilers got to be weak from age, and the pressure had to be reduced, and so the speed could be maintained under all conditions.

The "Wyoming" was built at Philadelphia, and is 232 ft. long, 33 ft. beam, by 15 ft. 10 ins. deep, tonnage 997 tons, draught 13 ft. 3 ins. There were two direct-acting engines with double piston rods, slide valves and independent cut-off valves, one surface condenser, cylinders not jacketed, 50 ins. diam. by 2 ft. 6 ins. stroke; two large Martin boilers, and one small one for donkey boiler, grate surface 242 sq. ft., heating surface 7,890 sq. ft., propeller 12 ft. 3 ins. diam. by 19 ft. pitch, speed 9 knots, coal per hour 1461 lbs., coal per I. H. P. 3 lbs. per hour, steam pressure 22 lbs.

The "Mohican" was built at Portsmouth, N. H., and is 233 ft. long, 33 ft. beam, 16 ft. deep, and 13 ft. draught, tonnage 1000 tons. Has direct-acting engines,

with two cylinders 54 ins. diam. by 30 ins. stroke. Two Martin Boilers. Propeller 12 ft. 9 ins. diam. by 19 ft. pitch, revolutions per minute 80.

The "Dacotah" was built at Norfolk, Va., and was 227 ft. long, 32 ft. beam, 13 ft. draught, tonnage 1085 tons. Two cylinders 63 ins. diam., by 36 ins. stroke. Propeller 12 6 ins. diam. by 18 ft. pitch.

The "Seminole" was built at Pensacola, and was 219 ft. long, 31 ft. beam, 14 deep, tonnage 801 tons. Two back-acting engines, cylinders 50 inch. diam. by 36 stroke, surface condenser. Two Martin boilers, and donkey boiler with one furnace. Propeller 9 ft. 6 ins. diam. by 17 ft. pitch, I. H. P. 750, coal per day 22 tons.

The "Pawnee" was built at Philadelphia; she was 238 ft. long, 47 ft. beam, tonnage 1289 tons. Two horizontal direct-acting engines, cylinders 65 ins. diam. by 3 ft. stroke. Martin boilers. Two propellers each 9½ ft. diam.; these engines had a series of four gear-wheels connecting to the propeller-shaft, which caused the propellers to revolve in opposite directions; these wheels never worked satisfactory, which caused the ship to be a partial failure.

The "Narragansett" was built at Boston, and was 188 ft. long, 32½ ft. beam, 14 ft. deep, draught 9 ft. Two horizontal back-acting engines, cylinder 48 ins. diam. by 28 ins. stroke. Two Martin boilers and one

auxiliary boiler; propeller 9½ diam. by 18 ft. pitch.

The machinery for these sloops was built under the superintendence of Samuel Archbold, Engineer-in-Chief U. S. N., with back-acting engines and surface condensers; was the most compact, most economical in fuel, and had the greatest coal endurance of any machinery in the navy up to that time.

The "Saginaw" was a side-wheel steamer, and was built at Mare Island, Cal.; she was 163 ft. long, 26 ft. beam; tonnage 456 tons; two inclined oscillating engines overhung paddle-wheels, 20 ft. diam. by 6 ft. face; two boilers; bunkers carry 100 tons of coal; consumption 5 tons per day.

In 1859 W. H. Webb, of New York, completed building the "General Admiral" for the Russian Government; she was 308½ ft. long, 54½ ft. beam, 33½ ft. deep, tonnage 4,036 tons, draught 23 ft. This vessel had horizontal back-acting engines, built at the Novelty Works, N. Y., cylinders 84 in. diam. by 45 in. stroke, with jet condenser, propeller 19 ft. diam. by 30 ft. pitch, six return tubular boilers, grate surface 700 sq. ft., heating surface 21,000 sq. ft., revolutions per minute 50, speed 13 knots, average speed at sea 12.7 kuots.

In June, 1861, soon after the commencement of the Civil War, the Uuited States Government contracted for the building of twenty-three gunboats, to be

built from plans and specifications furnished by J. Lenthall for the hulls, and by B. F. Isherwood for the machinery.

These boats were built of wood and were called the ninety-day gunboats, as it was expected that they could be built in that time.

The "Winona", built by C. & R. Poillon, of N. Y., and the "Penobscot" built by Carter, of Belfast, Me., with engines built by the Allaire Works, N. Y., may be taken as examples of the others. They were 158 ft. long, 28 ft. beam, 12 ft. deep, tonnage 559 tons, draught 10 ft.

The engines were on the horizontal back-acting plan, but with one piston-rod connected to a cross-tail, which was connected to the cross-head by two side rods, one above the crank-shaft and one below it; two cylinders 30 in. diam. by 18 ins. stroke, the slide valve to have sufficient lap to cut off at ⅔ of the stroke, link motion. Sewell's surface condenser: two Martin boilers, grate surface, 88½ sq. ft., heating surface, 2700 sq. ft. steam pressure, 30 lbs., one Dimphel blower and engine for forced blast; revolutions 90 per minute; speed 9½ knots, propeller 9 ft. diam. by 12½ ft. pitch.

At a cruising speed of 71 revolutions, and with 20 to 25 lbs. steam pressure, the consumption was 634 lbs. of coal an hour, or 6.8 tons per day, and the speed was

6.8 knots. I. H. P. 200, coal per I. H. P. per hour 3.2 lbs. These engines were unusually heavy in all their parts, for instance, the piston-rods were 5 ins. diam., which was the usual size for a 50 ins. cylinder on a merchant steamer, or 2.78 times stronger than was necessary, and the other parts were in about the same proportion.

In 1861, soon after ordering the gunboats, the U. S. Govt. ordered the following vessels of about 1020 tons to be built. The "Oneida," "Kearsarge," "Wachusett," "Ossipee," "Housatonic," "Juniata," "Tuscarora" and "Adirondac." The engines of the "Oneida" were duplicates of the engines on the "Iroquois," except that she had a Sewell condenser, and a fixed four-bladed screw propeller.

The engines on the "Kearsarge"—that sunk the "Alabama"—and "Wachusetts" were similar to those on the "Mohican" and "Seminole."

The engines on the other five vessels were of the Govt. type, with 42 ins. cylinders, by 30 ins. stroke.

In 1862 it was found that the gunboats were of little value to establish the blockade, as they were too slow; a vessel going 9 knots could not, of course, catch a blockade-runner going 12 to 14 knots, and besides the "Alabama" had so startled the commercial public, that there was a general outcry for fast war vessels. And

so the Navy Department set to work to provide a fleet capable of overhauling and catching her. They built three types of vessels. The first was a fleet of screw sloops as follows: The "Lackawanna," "Ticonderoga," "Canandaigua," "Shenandoah," "Sacramento" and "Monongahela."

The "Lackawanna" may be taken to represent the others; she was built at the Brooklyn Navy Yard by constructor B. F. Delano, and was 256 ft. long over all, 38¼ ft. beam, 17 ft. 8 ins. deep, tonnage 1610 tons, draught 15 ft. The engines were built at the Allaire Works, N. Y., from plans and specifications by B. F. Isherwood, Chief of the Bureau of Steam Engineering.

They were horizontal back-acting engines, with one piston-rod connected to a crosstail, which was connected to the crosshead by two side-rods, one above the crank-shaft and one below it. Two cylinders 42 ins. diam. by 30 ins. stroke; the slide-valves were on the outsides of the cylinders, stood on edge, and were made with sufficient lap to cut off at two-thirds of the stroke, and worked by link motion for reversing and backing. Sewell's surface condenser. Propeller four-bladed, and fixed on the shaft, diam. 15 ft., mean pitch 17½ ft.

Two Martin boilers, and one auxiliary boiler, with 14 furnaces in all, grate surface 273 sq. ft., heating surface 8950 sq. ft., steam pressure 30 lbs., two Dimphel

blowers and engines for forced draft, maximum revolutions 68, I. H. P. 8 to 900, speed 11½ knots.

When these vessels were going at full speed, and with steam of 30 lbs., there was very little expansion, (cutting off at two-thirds in a small cylinder), for the power developed, and in consequence of this, the consumption was about 28 to 30 tons coal per day, and the coal per I. H. P. from 3 to 3½ lbs. per hour. The engines were unusually heavy in all their parts, the piston-rod was 7 ins. diam., which was the usual size for a 68 ins. cylinder on merchant steamers, and the other parts strong in proportion.

The second type was a fleet of (what was called) "double-enders," as follows: The "Octorara," "Tioga," "Tennessee," "Sonoma," "Mahaska," "Paul Jones," "Port Royal," "Miami," "Cimerone" and "Conemaugh."

One of these vessels, the "Octorara," built at the Brooklyn Navy Yard, will represent the others. She was 207 ft. long, 35 ft. beam, by 12 ft. deep, tonnage 800 tons, draught 6 ft. 9 ins. There was one inclined engine, cylinder 44 ins. diam. by 7 ft. stroke, with balanced poppet valves, arranged with Stevens' cut-off, and two eccentrics, one for going ahead, the other for backing, Sewell's surface condenser, overhung paddle wheels 22 ft. diam. by 8 ft. face; two boilers with ver-

tical water tubes, each with three furnaces, grate surface 97½ sq. ft., heating surface 3000 sq. ft., steam pressure 30 lbs., cut-off at ⅔ of the stroke, forced blast by means of Dimphel blower and engine, speed 12 to 13 knots.

These vessels were similar to the Union ferry boats in New York harbor, fitted with a rudder on each end, so as to go with either end foremost; coal per I. H. P. per hour about 3 to 3½ lbs.

The third type, or class, consisted of a fleet of twenty-seven double-enders as follows: "Winooski," "Peoria," "Algonquin," "Ascutney," "Agawam," "Iasco," "Metacomet," "Mendota," "Mackinaw," "Lenapee," "Mattabesett," "Mingoe," "Massasoit," "Otsego," "Osceola," "Pontoosuck," "Pontiac," "Patuxet," "Sassacus," "Shamrock," "Tacony," "Tallapoosa," "Wyahusing," "Chicopee," "Chenango," "Tallahoma," and "Eutah."

One of these vessels, the "Winooski," built at the Boston Navy Yard, will represent the others. She was 240 ft. long, 35 ft. beam, by 12 ft. deep, tonnage 1060 tons, draught 8½ ft. The engine was built at the Etna Iron Works, N. Y., and was inclined, cylinder 58 ins. diam. by 8 ft. 9 ins. stroke, with balanced poppet valves, and Stevens' cut-off gear, set to cut-off at two-thirds of the stroke; Sewell's surface condenser, overhung paddle wheels, 26 ft. diam. by 9 ft. face; two Martin's

vertical tubular boilers with five furnaces in each, grate surface 195 sq. ft., heating surface 4900 sq. ft., steam pressure 30 lbs., speed on trial 16 miles an hour, revolutions deep, 16 per min., light, 21 per min.

The "Winooski," on a speed trial on Long Island Sound, with 40 lbs. steam, and with blowers going, made 26 revolutions per minute; coal per I. H. P. 3 to 3½ lbs. per hour; cubic ft. in the cylinder 160.

The "Algonquin" had an inclined engine with single poppet valves, and Dickerson and Sickels' valve gear, cylinder 48 ins. diam. by 10 ft. stroke, cubic ft. in cylinder 125.5; two Dickerson's, inclined water tube heating, and vertical fire tube superheating boilers.

In 1865 a competitive duty trial was made at the dock, foot of Delancy St., N. Y., between the "Winooski" and "Algonquin," for 96 consecutive hours, (to show economy of fuel in proportion to power,) with the paddle wheels reduced to 22 ft. diam. over the buckets.

Before this trial began the cut-off on the "Winooski" was altered, so as to cut off at ⅙ on the down stroke, and 1–5 on the up stroke.

The "Winooski" ran the 96 hours trial successfully, and the indicator cards, dated Dec. 4th, 1865, showed that the engine made 14.8 revolutions with 35 lbs. steam, cutting off at ⅙ on the upper, and 1–5 on the lower end of the cylinder.

The "Algonquin" ran for 48 hours, and then stopped on account of the superheating tubes leaking, and the escaping steam mixing with the soot choked the draught, and prevented the trial being continued.

The cut-off on the "Winooski" was afterwards set back to the ⅔ point as before fixed.

Thus it appears that the Navy Department turned Dickerson's guns (expansion and large cylinder) against himself, and fought him with his own weapons; they cut off at 1–5 and ⅙ in a cylinder 28 per cent. larger than Dickerson's.

In June 1863, during the dark days of the rebellion, just before the battle of Gettysburgh, and the surrender of Vicksburgh to Gen. Grant, when the U. S. Government was menaced by the Governments of Great Britain, France and Spain, threatening to recognize the Confederacy, and to intervene in Mexico, to establish an Empire there, and before the July riots in New York. The U. S. Government decided to build the following vessels: the "Wampanoag," "Ammonusuc," "Neshaminy," "Pompanoosuc," "Madawaska," "Chattanooga," and "Idaho," of 3500 tons. These vessels were designed to be as fast as it was possible to build Men-of-War.

The Government also decided to build another class of vessels a little smaller, as follows: the "Java,"

"Ontario," "Kewaydin," "Guerriere," "Minnetinka," "Antietam," "Illinois," "Piscataqua," "Mosholu," "Contocook," "Pushmataha," "Manitou," "Hassalo," "Mondaman," "Neoranquo," "Williamette," "Sagaquata," "Watanga," "Aropho," and "Winaloset," of 3200 tons, and less power than the others had.

It was claimed that the commencement of these vessels, which was widely advertised, prevented the recognition of the Confederacy by the three aforementioned powers, and that the compact was broken, so that the French only, went into Mexico. It was also claimed that, although the machinery of some of them was a total failure, yet the effect produced by them preventing foreign interference, was well worth all that they had cost the Government.

The "Wampanoag," "Ammonoosuc," and "Neshaminy," were 335 ft. long, 44 ft. beam, by 23½ ft. deep, tonnage 3500 tons, built in the Navy Yards. The engines were horizontal direct-acting geared engines, designed by B. F. Isherwood, cylinders 100 ins. diam. by 4 ft. stroke, geared about two to one; the valves were on the outside of the cylinders, and stood on edge, and operated by link motion gear, surface condenser. There were eight vertical tubular main boilers, and four superheating boilers, arranged with two firerooms, one forward and one aft of the engines, with the propeller

shaft in the middle of it; grate surface 1128 sq. ft., heating surface 31,148 sq. ft., propeller 18 ft. diam. by 25 ft. mean pitch, four blades.

The "Wampanoag" went in commission and made a cruise at sea from Feb. 7th to 17th, 1868, and according to the official report her maximum speed was 17 knots, revolutions of engines 32 per min., of screw 64 per min., I. H. P. as per indicator cards 3895, coal per hour 13,371 lbs., coal per I. H. P. per hour 3.43 lbs., steam pressure 37 lbs.

At a speed of 11½ knots, steam pressure 15½ lbs., the revolutions were 20 per min., I. H. P. 990, coal per hour 3562 lbs., coal per I. H. P. per hour 3.6 lbs.

The "Wampanoag" made the 96 hours dock trial Dec. 21st, 1867, steam 42 lbs., revolutions 24 per min.

The "Ammonoosuc" made the 96 hours dock trial May 8th, 1868, steam pressure 30.5 lbs., and 27 revolutions per min.

The "Neshaminy" made the 96 hours dock trial Nov. 13th, 1868, steam 34 lbs., revolutions 30.5 per min., the engines working well during the trial.

It was found on inspection, Nov. 16th, 1868, that the wooden cogs of the spur gear wheel of the "Neshaminy" had worn down during the 96 hours trial ⅝ of an inch, the crushed wood lay under the wheel, and the cogs on the "Wampanoag," (which lay along-side), had

worn about ¼ of an inch.

The "Neshaminy's" engines having made more revolutions than those of the "Wampanoag," accounted for the increased wear. In consequence of this defect, and the deficient acommodation for the crew, caused by the between-decks being taken up for coal bunkers, the "Neshaminy" and the "Ammonoosuc" never went in commission, but were laid up until they rotted.

About 1871–2 the "Neshaminy's" machinery, which cost $680,000, was sold back to the builder for $46,000, and was used in the construction of the new compound engines for the "Tennesse," formerly the "Madawaska."

The "Pompanoosuc" was never completed.

The "Madawaska" was fitted with a pair of Ericsson's bell crank engines, cylinders 100 ins. diam. by 4 ft. stroke, by the Allaire Works Co. N. Y. There were only two journals to the crank shaft, which prevented the engines from being worked up to their power on account of hot journals, the ship could only go about 12 knots, although she had power to propel her 16 knots. The engines were removed, and new horizontal tandem compound engines, with two cylinders 40 ins., and two 78 ins. diam., by 40 ins. stroke, were fitted, of smaller power, which made her a useful ship, gave room for the crew, was economical in fuel, and gave a speed of 13 knots. She was then called the "Tennessee"

The "Chattanooga" was built by Cramp, with two direct-acting engines by Merrick & Sons, Philadelphia, cylinders 84 ins. diam. by 3½ ft. stroke, propeller 18 ft. diam. by 29 ft. pitch; eight horizontal tubular boilers, speed about 13 knots.

The "Idaho" was fitted with Dickerson's engines, built at the Morgan Works N. Y. There were four cylinners 30 ins. diam. by 8 ft. stroke; two propellers 14 ft. diam. The ship was not very successful, and the engines were finally removed, and the ship fitted as a sailing ship.

There were few of the ships of the "Java" and "Ontario" class, of 3200 tons, ever finished.

They were 315 ft. long, 47 ft. beam, by 23 ft. 9 ins. deep; the engines were of the horizontal back-acting type, two cylinders 60 ins. diam. by 3 ft. stroke, propeller 17 ft. diam. by 28 ft. pitch. Four main boilers and two superheating boilers, surface condenser, flat slide valves, with link motion for reversing and cut off. The ships were slow, as the cylinders were small, and the steam was not expanded much, consequently they were expensive on fuel. Many of these engines were stored at the Brooklyn Navy Yard, and afterwards sold for old material.

It may be asked why the machinery of this great fleet of nearly one hundred steam vessels was construct-

ed on the principle of cutting off at two-thirds of the stroke, and so expanding the steam of 30 lbs. pressure only one and one-half times, notwithstanding the examples furnished in the "Iroquois," "Wyoming" and "Mohican," and the results obtained in these vessels, under the superintendence of S. Archbold, Engineer in Chief U. S. N.

The reply will be found in the fact, that B. F. Isherwood, the new Engineer in Chief, had a theory, which was promulgated in a report of the Board of U. S. Naval Engineers, to the Hon. Isaac Toucey, Secretary of the Navy, and dated Erie, Pa., Feb. 18, 1861.

This Board was composed of B. F. Isherwood, Theo. Zeller, Robt. H. Long, and Alban C. Stimers.

The report gave an account of a series of experiments tried on the U. S. steamer "Michigan," in the Lake harbor of Erie, Pa., with the vessel moored to the wharf, from Nov. 10, 1860, until date.

There were seven experiments tried under various degrees of expansion, namely, 4–45, 1–6, 1–4, 3–10, 4–9, 7–10 and 11–12 of the stroke; each of these experiments continued 72 consecutive hours, with a constant boiler pressure of 21 lbs.; the steam was cut off by a Sickels gear; there were two engines, cylinders 36 ins. diam. by 8 ft. stroke, one engine only was used, and the two boilers.

The experiments were made, "for the purpose of determining the Relative Economy in Rapport of fuel to power, of using steam with different measures of expansion." After a long and elaborate report with an illustration of the boilers and seven indicator cards showing the different degrees of expansion, also tabulated matter, the Board sums up to their own satisfaction as follows:

"The experiments have been made under the most favorable conditions, not only for obtaining exact comparative results, but for obtaining the maximum for the large measures of expansion. The boiler pressure was sufficiently high; the back and friction pressures, the minimum in practice; the organs of the engine were well proportioned, and functioned properly; the boilers furnished easily an abundant supply of steam, and never gave the slightest evidence of foaming. Every circumstance combined to render the results even hypercritically unexceptionable; yet in all respects, and under all possible changes of condition, they are conclusive against the popular belief in favor of high measures of expansion; for cutting off the steam at 7-10 of the stroke of the piston is scarcely recognized as working it expansively.

"With regard to steam jacketed cylinders, there are no published experiments on the results of which

we can safely base an opinion. Such a set of experiments have yet to be made, and are of the first consequence in engineering; but judging from our personal experience, we are by no means sanguine that, under proper conditions, with engines of and above the medium size, any gain greater than a few per centum can be made; or that this gain will not be as great when the steam is used without expansion, as when it is used expansively.

"All the claims for great economical gain by the use of steam very expansively have been asserted for engines of the same type as that employed for the experiments, and which are the kind almost universally employed for river and marine purposes, the engines in which the cylinder is steam jacketed, or in which superheated steam has been attempted, consisting of but a few exceptional cases."

From this extract of the report of the Lake Erie Board of which Mr. Isherwood was President, and his practice after he became Engineer in Chief of the U. S. Navy, it will appear that he ignored the examples of his predecessors, C. W. Copeland, C. H. Haswell, D. B. Martin and S. Archbold; they had all used the principle of expansion, cutting off at ½ stroke, and even less. Adam Hall on the Hudson River had cut-off at ¼ with 40 lbs. steam.

Stevens had introduced his cut-off which was generally used at ½ stroke; David Elder, and Maudslay, used separate expansion valves; James Watts' patents provided for working steam expansively, and for steam jackets. The Cornish Engineers had used steam of 30 lbs. pressure cut off at ⅙, and they invariably used steam jackets; John Elder was using steam jackets on his compound engines; James P. Allaire in N. Y., used high steam chimneys to dry and superheat the steam; David Elder used steam chimneys (or chests) on the early Cunard steamers, with expansion valves; and F. Sickels, who had the most perfect cut-off, had applied it on many steamers.

This Sickels cut-off, with Dickerson's improvements, were being introduced on the Naval steamers, "Richmond" and "Pensacola," at the Washington Navy Yard, and were to have single poppet valves, applied to the cylinder heads, so that they might be steam tight, and avoid unnecessary clearance in the steam ports.

These engines would no doubt have given good satisfaction, and produced good results, if they had received proper treatment, but as the principles embodied in this cut-off, interfered with the pet theory of the ⅔ cut-off, Mr. Isherwood seemed determined to destroy them, and did so in the end.

His treatment of Dickerson and Sickels was anything but fair and impartial.

The engines on the "Hu-Quang," 76 ins. cylinder, by 12 ft. stroke, and on the S. S. "Golden Rule," 81 ins. cylinder, by 12 ft. stroke, with single poppet valves, worked well for many years, until the vessels were wrecked.

The Sickels cut-off was successfully used on the Collins S. S. "Baltic," "Empire State," "Kill Von Kull," "Rhode Island," "Eagle," "City of Norwich," and "City of New London," "Suffolk" and "Kings County"; the Fall River Steamboats, "Bristol" and "Providence," and many others.

The purpose of the experiments was, "to determine the relative economy in (proportion) rapport of fuel to power, with different measures of expansion." But instead of having the power constant, and varying the steam pressure, the pressure was constant at 21 lbs., and the power varied, by reducing the paddles.

Consequently (if for no other reason) such experiments can have no practical value, besides 21 lbs. was taken as the pressure, when 30 lbs. had already been used by Mr. Archbold on the "Iroquois."

Then again see the absurdity of conducting a 72 hours experiment cutting off at 4–45, expanding eleven times, with steam at 21 lbs., and without a steam jacket,

or a superheating apparatus, (which is its equivalent); any novice knows that such an experiment is utterly absurd.

J. Bourne in his treatise on the steam engine published 1851, showed: "That if the steam be stopped at ½, its performance is multiplied 1.7 times; at ⅓, 2.1 times; at ¼, 2.4 times; at 1–5, 2.6 times; at ⅙, 2.8 times; at 1–7, 3. times, and at ⅛, 3.2 times." Of course we cannot have the same degree of expansion with low pressure steam as with high pressure, and then we must prevent cylinder condensation, either by steam jackets or by superheating.

J. W. Nystrom, also, in his Pocket Book of Mechanics and Engineering, published in Philadelphia 1861, showed the advantage of expanded steam, particularly when it was superheated, and what he had done in that way in Russia.

And yet in the light of all that, Mr. Isherwood in building the engines for the gun-boats and sloops, adopted the condenser and pump arrangement, and the boilers from the "Iroquois," but discarded the cut-off valve, and reduced thc capacity of the cylinder 21.5 per cent.

In Cornwall, (1842) with 30 lbs. steam, steam jacket, and ⅙ cut-off, one horse power was obtained from 2½ lbs. coal. On the "Iroquois," 2.8 lbs; on the "Wyom-

ing," 3 lbs.; on the gun-boats and sloops, 3¼ to 3½ lbs.; and on the "Wampanoag" class, from 3.43 to 3.6 lbs.

From all this it will be seen that the ⅔ cut-off theory was a most expensive one to the nation.

In some cases before 1869, a superheating apparatus was constructed to go in the uptake, but in order to be of much value, it would have to be used in connection with expanded steam.

When John Elder's compound engine was introduced in 1872–3, by the Pacific Mail Co., on the Philadelphia Line to Liverpool, and on the Mallory Line; with expanded steam, steam jackets, and superheater. Then the Lake Erie two-thirds cut-off theory fell to the ground, and the fallacy was exposed.

In 1861, W. H. Webb of N. Y., contracted to build two wooden armour plated frigates for the Italian Govt. They were the "Re d' Italia," and "Re Dou Luigi di Portogallo"; length 285 ft., beam 55 ft., depth 33 ft., tonnage 5,000 tons, armour plate 4½ ins. thick. The machinery consisted of two horizontal back-acting engines, cylinders 84 ins. diam. by 45 ins. stroke, with slide valves, and cut-off valves on the back, propeller 20 ft. diam. by 31 ft. pitch. Six return tubular boilers, grate surface 700 sq. ft., heating surface 21,000 sq. ft., revolutions 50 per min., speed 12½ knots an hour.

In Jan. 1862, the "Monitor" was launched at Greenpoint, Brooklyn. This vessel was designed by J. Ericsson, built of iron, and was 174 ft. long, 41 ft. beam, and 11½ ft. deep. The engines were horizontal, with two cylinders 40 ins. diam. by 22 ins. stroke, built at the Delamater Iron Works, N. Y., connected by bell cranks and rods to one crank on the propeller shaft, the connecting rods being arranged at right angles to one another, the valves were on the side of the cylinders, and had an adjustable plate on the back to relieve the pressure, no cut-off valve. This vessel arrived at Newport News, Va., on March 9, 1862, and fought with the Ram, "Merrimac" on that day, speed about 8 knots an hour.

Many vessels of this type were built during the years of the civil war.

On December 26, 1863, the iron clad monitor, "Dictator," was launched at the Delamater Iron Works, N. Y. She was also designed by J. Ericsson; length 314 ft., beam 50 ft., depth 22½ ft.

The engines were built at the same works, and had two vertical cylinders 100 ins. diam. by 4 ft. stroke, with trunks in the upper ends, the pistons were connected through the trunks to the bell crank shafts, and they were connected to one crank on the propeller shaft, the weights of the pistons, trunks, links, bell crank arms, and connecting rods, were all centered on the one crank

pin; and to balance these weights, there was a counter-balance weight cast on a large overhung crank wheel in which the crank pin was secured; a light crank and shaft led forward to work the eccentrics.

The air pumps were worked from the bell crank shafts extended. Propeller 21½ ft. diam. by 34 ft. pitch. There were six boilers with two tiers of furnaces and vertical water tubes above them, grate surface 1128 sq. ft., heating surface 32,000 sq. ft.

Owing to the crank wheel being overhung, and only one journal being provided to receive the strain and wear, of these two engines of 5000 I. H. P. the result was, that the engines would propel the vessel about 9 knots, with the upper brass and binder of the crank shaft left off, and they would not do any more with them on, on account of that journal getting hot. Sperm, Olive, and Castor oils were used, but it was of no use, as the engines and boilers, with sufficient power to drive the ship 15 knots, could not be driven to propel her continuously, more than 9 to 9½ knots.

In consequence, the engines proved to be a complete failure.

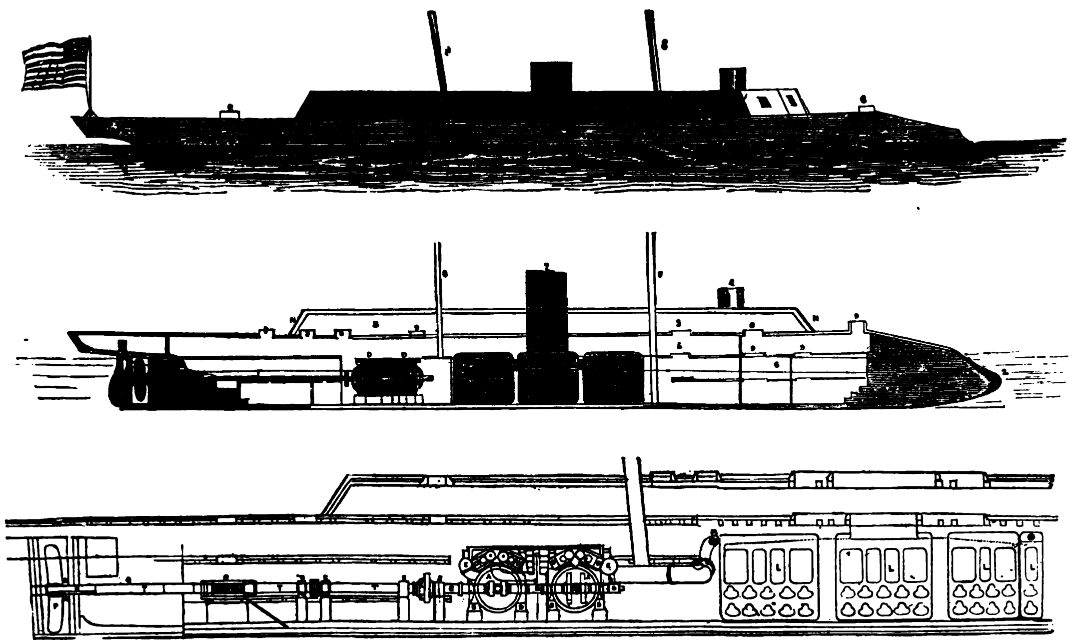
The "Puritan," a sister ship was launched July 2, 1864, she was never finished, but was sent to Chester, Pa., where John Roach & Son cut her up and built a new "Puritan," a ship-shape vessel, 290 ft. long, 60 ft.

beam, 20½ ft. deep, with double bottom 3½ ft. deep, which was launched Nov. 6, 1882. This vessel was fitted with twin screws, 15 ft. diam. by 21 ft. pitch, and two pairs of compound horizontal engines, cylinders 50 ins., and 86 ins. diam., by 3½ ft. stroke. There are ten cylindrical return tubular boilers with three furnaces in each, grate surface 570 sq. ft., heating surface 17,000 sq. ft., steam pressure 80 lbs., revolutions 68 per min., I. H. P. 3300.

Owing to the delay in making an appropriation in Congress for armour plate, this vessel is not yet completed, but promises to be an efficient, seaworthy, and formidable vessel. She is now (1893) at the Brooklyn Navy Yard receiving the armour plate, two turrets, and outfit, is nearly complete.

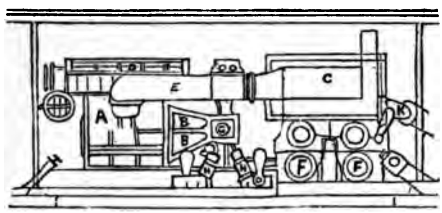
In 1862, W. H. Webb of New York contracted with the U. S. Govt. to build the Steam Ram, "Dunderberg." This vessel was built of wood, 370 ft. long, 72 ft. beam, by 22½ ft. deep, draught 21 ft., displacement about 8000 tons, armour plate 4½ ins. thick, tapering to about 3 ins., speed 15 knots.

The machinery was built by John Roach at the Etna Iron Works, N. Y., and consisted of two horizontal back-acting engines, designed by T. Main, on the plan of the engines of the U. S. Steamer, "Iroquois," (also designed by him); the cylinders were 100 ins.



Steam Ram_"Dunderberg."

diam. by 45 ins. stroke, with independant air and circulating pumps, (proposed by E. W. Smith, and built by H. R. Worthington), flat slide valves with cut-off valves on the back, adjustable by right and left screws, and a ring on the back to relieve the pressure, propeller of brass, 21 ft. diam. by 28½ ft. mean pitch, and fixed on the shaft. There were six main boilers and two donkey boilers—designed by E. W. Smith, Supt. for Mr. Webb



ENGINES OF THE "DUNDERBERG."

—with two tiers of furnaces, and return horizontal tubes above, grate surface 1250 sq. ft., heating surface 30,000 sq. ft., steam pressure 25 lbs., maximum revolutions per min. 62, I. H. P. 6000, speed 15.3 knots an hour.

This vessel was not completed until Sept. 1866, owing to the delay with the machinery.

When Mr. Roach contracted for this work, he had never built an engine, knew little about engineering, was an iron moulder, had a small foundry, where he

made castings for house-work, and bridge work for the Harlem Bridge, had a few tools for fitting up such work.

At the same time he contracted to build an oscillating engine for a steamboat, cylinder 66 ins. diam. by 10 ft. stroke. Two inclined engines for two double-ended gunboats, cylinders 58 ins. diam. by 8 ft. 9 ins. stroke. Also two sets of double engines, cylinders 44 ins. diam. by 3 ft. stroke, for the Providence screw steamboats, "Electra" and "Galatea."

In Dec. 1862, Mr. Roach associated T. Main with him as his Superintendent, and this connection existed for many years. Mr. Main had been Supt. Engineer at the Allaire Works, N. Y., Draftsman at the Fulton Iron Works, N. Y., and had been assistant to David and John Elder in designing and constructing the engines of the Cunard steamers and others, from 1847 to 1854, in the Vulcan Foundry, and Lancefield Works of Robt. Napier of Glasgow.

Under these circumstances Roach commenced his great career, and he often said in succeeding years, that for whatever success he had attained, he was largely indebted to Mr. Main for it.

No doubt but that Mr. Webb's patronage greatly helped his credit with the merchants, and at the banks; but after all, his credit was chiefly based on his engi-

neering success, and at that time he did his business largely on a credit basis.

He built in succession, boiler shop, foundry extension, machine shop, blacksmith shop, coppersmiths shop, brass foundry, and fitted them with engines, shafting, travelling and swing cranes, planers, lathes, boring mill, slotters, punches, shears, rollers, drills and other tools, and before the engines for the "Dunderberg" were finished, and those before mentioned. He built also the engines for the (boilers, wheels, and repaired the engine for the "Guiding Star," 81 ins. by 12 ft.), "Rising Star" 100 ins. by 12 ft., "Nebraska" 81 ins. diam. by 12 ft. stroke, "Palmilla" double engines 36 ins. by 8 ft. stroke, "Bristol" and "Providence" 110 ins. cylinder by 12 ft. stroke; two pairs of 60 ins. by 3 ft. stroke engines, and one pair of geared engines for the "Neshaminy," cylinder 100 ins. diam. by 4 ft. stroke, for the U. S. Govt., were well under way, besides finishing the Harlem Bridge at the head of Third Ave., N. Y., and other miscellaneous work.

Before the "Dunderberg" was finished the war was over, and the U. S. Govt. had no need of the vessel. Meanwhile Mr. Webb had an opportunity to sell her to the French Govt., and the U. S. Govt. gave their consent.

The "Dunderberg" sailed for Cherbourg on July

19th, 1867, and was there called the "Rochambeau." On a trial there with a French crew, she made a speed of 15.3 knots an hour, but being a wooden vessel covered with armour plate she soon met the fate of all such vessels, that is the wood behind the iron decayed.

In 1873 Congress ordered the building of seven small sloops, and one large vessel. The sloops were the "Allert" and "Ranger," built of iron, and the "Essex," "Alliance," "Adams," "Huron" and "Enterprise," of wood; they were about 175 ft. long, 32 ft. beam, and 10 ft. 3 ins. deep, tonnage 620 tons.

The engines were horizontal back-acting compound, cylinders 34 ins. and 51 ins. diam. by 42 ins. stroke, built in part from a competitive design by T. Main, to whom was awarded a premium of $1000; namely, one-half for the counterbalancing feature, and one-half for the best plan presented in competition with the plans of the Navy Department. The cylinders were both steam jacketed, slide valves on the outsides of the cylinders with cut-off valves on the backs of them, the high-pressure cylinder had one piston rod connected to a cross-tail, which was connected to the crosshead by two side rods. The low-pressure cylinder had two piston rods which connected to the crosshead, one went over and the other under the crank shaft, surface condenser, counterbalance ends on the low-pressure cranks, and

placed at such an angle as to balance the cranks on both engines, propeller 14 ft. diam. by 19 ft. pitch. There were eight boilers with one furnace in each, 4 ft. 6 ins. diam., grate surface 192 sq. ft., heating surface 4800 sq. ft., steam pressure 80 lbs. These boilers were not very successful, the furnaces threatened to collapse, and they were replaced by boilers with two furnaces in each, as in the competitive design.

The "Trenton"—the larger vessel—was built of wood at the Brooklyn Navy Yard, and was about 2000 tons. The engines were three cylinder compound, built by J. Roach in N. Y., one high-pressure cylinder 58½ ins. diam. and two low-pressure 78 ins. diam. by 4 ft. stroke.

Eight cylindrical tubular boilers with three furnaces in each, grate surface 504 sq. ft., heating surface about 15,000 sq. ft., steam pressure 80 lbs. This proved to be a very serviceable vessel, and after a successful career she was lost in a hurricane at Samoa in the Pacific Ocean.

In 1882 Congress authorized the construction of four unarmoured cruisers—the "Chicago" of 4500 tons, the "Boston" and "Atlanta" of 3000 tons each, and the "Dolphin" of 1500 tons—to be built subject to the directions of an Advisory Board to be appointed by the Secretary of the Navy,.

In 1883 John Roach of N. Y. and Chester, Pa., contracted to build these vessels. The "Chicago" was 315 ft. long, 48 ft. 2 ins. beam, by 31 ft. 4 ins. deep, double bottom 42 ins. deep, mean draught 19 ft., protective steel deck 1½ ins. thick. Two propellers 15½ ft. diam. by 22½ ft. mean pitch. There were two sets of vertical compound beam engines, with slide valves, and cut-off valves on the high-pressure cylinders, surface condenser, independent air, and circulating pumps. Cylindrical tubular boilers, externally fired, furnaces lined with fire brick, steam pressure 80 lbs., I. H. P. 5000, speed 15⅓ knots an hour, coal per I. H. P. per hour about 2 lbs.

The "Boston" and "Atlanta" were sister vessels, length 270 ft., beam 42 ft., depth 26 ft., double bottom 40 ins. deep, protective steel deck 1½ ins. thick, draught 17 ft. There were three horizontal engines, one high-pressure cylinder 54 ins. diam. and two low-pressure 74 ins. diam. by 42 ins. stroke, surface condenser, independent air, and circulating pumps. Propeller 17 ft. diam. by 20 ft. pitch, I. H. P. 3500. There are eight boilers with two furnaces in each, grate surface 400 sq. ft., heating surface 10,000 sq. ft., steam pressure 80 lbs., speed 15 knots, coal per I. H. P. per hour about 2 lbs.

The "Dolphin" was 240 ft. long, 32 ft. beam, 19 ft. 9 ins. deep, draught 14¼ ft. The engines were of

the vertical overhead cylinder type, with surface condenser athwartship between them, cylinders supported on wrought iron columns diagonally braced, cylinders 42 ins. and 78 ins. diam. by 4 ft. stroke, slide valves, and cut-off valve on the high-pressure cylinder, independent air, and circulating pumps.

There are two double-ended and two single-ended cylindrical tubular boilers, with two firerooms, steam pressure 80 lbs., I. H. P. 2240, speed 15½ knots, coal per I. H. P. per hour 2 lbs.

In 1887 the U. S. ships, "Newark," "Charleston," "Baltimore," "Philadelphia," "San Francisco," "Yorktown," "Concord" and "Bennington," were commenced.

The "Newark" is 300 ft. long, 49 ft. 2 ins. beam, draught 18 ft. 9 ins. mean, speed 20.4 knots, twin screws and two sets of engines, steam pressure 150 lbs., displacement 4083 tons, I. H. P. 10,500 maximum, coal per I. H. P. per hour about 1.5 lbs.

The "Charleston," "Baltimore," "Philadelphia" and "San Francisco," are similar to the "Newark."

The "Yorktown," "Concord" and "Bennington" are 234 ft. long, 36 ft. beam, 14 ft. mean draught, displacement 1700 tons, I. H. P. 3600 maximum, speed 16.6 knots.

Two sets of triple-expansion engines, cylinders 22 ins., 31 ins. and 50 ins. diam. by 30 ins. stroke, fitted with

liners but unjacketed, which is singular in view of the great economy of steam jackets when properly applied and worked, with high pressure steam, piston valves; air, circulating, and bilge pumps independent of the main engines; two three-bladed screws about 10½ ft. diam. There are four cylindrical horizontal tubular boilers, grate surface 220 sq. ft., forced draught by closed fireroom. Coal per I. H. P. per hour about 1.5 lbs.

Since 1889 the U. S. Govt. have begun the construction of seven armoured ships, the "Maine," "Texas," "Monterey," "New York," "Indiana," "Massachusetts" and "Oregon"; and seven cruisers known as Nos. 6, 7, 8, 9, 10, 11 and 12.

The "Maine" may be taken as an example of the others; she is 324 ft. long, 57 ft. beam, mean draught 21 ft. 6 ins., displacement 6682 tons, speed 17 knots, and was built at the Brooklyn Navy Yard.

The engines were built at the Quintard Iron Works N. Y. There are two sets of vertical triple-expansion engines, cylinders 35½ ins., 57 ins. and 88 ins. diam. by 3 ft. stroke. There are to be eight cylindrical return tubular boilers, with three furnaces in each, grate surface 553 sq. ft., heating surface 18,800 sq. ft., steam pressure 135 lbs., forced draft under the grate bars; two three-bladed propellers 15 ft. diam.

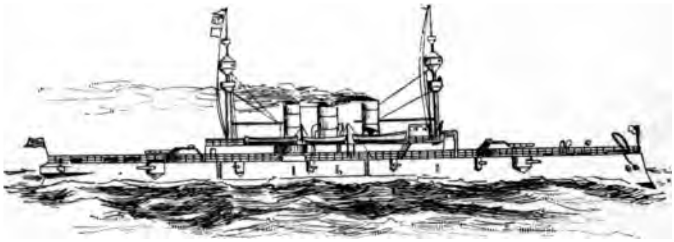
This vessel was launched Nov. 18, 1890, but none

of this class are yet finished.

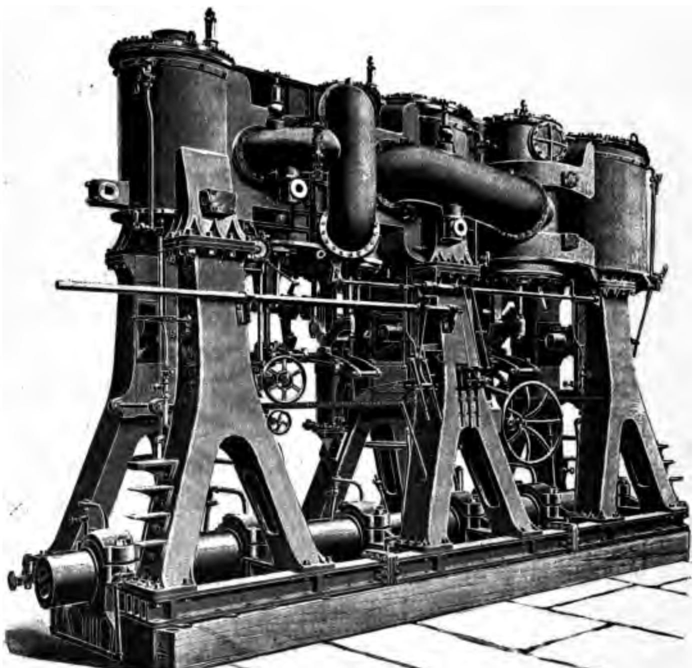
Protected cruiser No. 6, may be taken as an example of some of the others; she is 340 ft. long, 53 ft. beam, 21½ ft. mean draught, displacement 5500 tons, I. H. P. 13,500, speed 20 knots. There will be two sets of triple-expansion engines, cylinders 42 ins., 59 ins. and 92 ins. diam. by 42 ins. stroke, revolutions 129 per min.; grate surface in boilers 824 sq. ft., heating surface 28,-300 sq. ft., steam pressure 160 lbs.

The twin screw armoured cruiser, "New York," is 380 ft. long, 64 ft. 10 ins. beam, by 23 ft. 6 ins. draught, displacement 8,150 tons. She has two sets of triple-expansion engines to drive each propeller, the cylinders are 32 ins., 46 ins. and 70 ins. diam. by 3 ft. 6 ins. stroke, liners in cylinders, but not used for steam jackets, (which seems singular), piston valves. Six double-ended boilers with eight furnaces in each, and two auxiliary boilers, grate surface 988 sq. ft., heating surface 31,000 sq. ft., steam pressure 160 lbs.; two three-bladed propellers 16 ft. diam. by 20 ft. pitch, revolutions 129 per min., mild forced draught, speed on trial 20 to 21 knots, three smoke pipes.

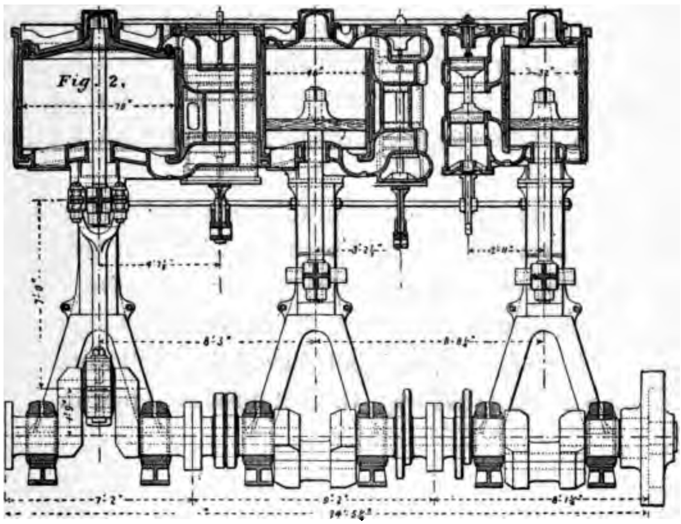
Cruiser No. 12, known as the "Pirate," is another example, and is 412 ft. long, 58 ft. beam, 24 ft. draught, displacement 7475 tons, I. H. P. 21,000 maximum, speed 22 knots. There will be three screw propellers, and

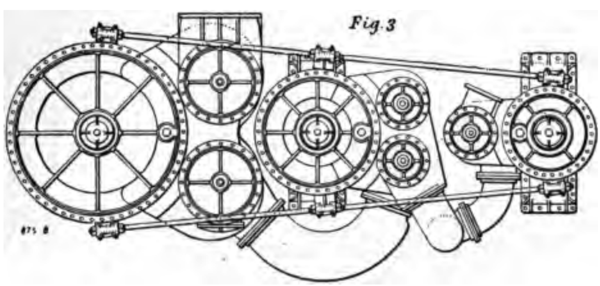


ARMORED CRUISER NEW-YORK.



ENGINES OF THE "NEW YORK."





ENGINES OF THE "NEW YORK."

three sets of triple-expansion engines, cylinders 42 ins., 59 ins. and 92 ins. diam. by 3½ ft. stroke, revolutions 129 per min. There are six cylindrical boilers with eight furnaces, and two with six furnaces in each, grate surface 1285 sq. ft., heating surface 43,272 sq. ft., steam pressure 160 lbs., probable consumption 1.5 lbs. per I. H. P. per hour.

It is the intention to run this vessel full power with the three screws, two-thirds power with the two outboard screws, and one-third power with the centre screw, as may be necessary, the engines working at full power in each case, as it is believed they will work with more economy that way, than at a reduced power.

CHAPTER VII.—Conclusion.

In the foregoing statements I have endeavored to give some examples in the progress of marine engineering, from the time of Watt until the present day, prudence suggests that it is desireable to know what progress others have made, before we attempt to progress ourselves.

At the present time (1893) when steamers are built, and being built to steam 20 to 27 knots an hour, and to develop from 20,000 to 45,000 I. H. P., it is important that this power should be produced at a small expenditure of coal. It has been demonstrated in theory that .2 lbs. of coal will produce one horse-power, and yet on first-class Atlantic steamers with triple-expansion engines and 180 lbs. steam, 1.5 lbs. of coal is still required for one horse-power per hour.

It may be interesting to trace some of the causes of this discrepancy.

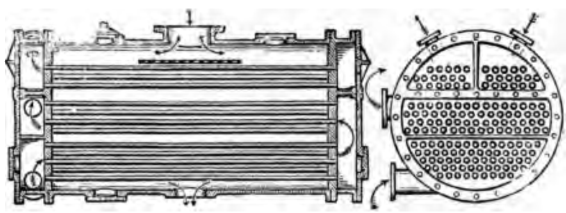
Before 1860, attempts had been made by Watt, Hall and others to produce a reliable surface condenser, in order to furnish fresh water to the boilers, with the view of using high-pressure steam, and to prevent the necessity of blowing off the salt and lime deposited in the boilers, from the sea water. It was then the custom to use copper or brass tubes, but the coperas from them was found to injure the boilers, grease and tallow from the cylinders, also got into the boilers and produced injurious results, the packing at the ends of the tubes also caused trouble.

But about this time the practice of tinning the brass tubes was introduced, and W. Sewell, H. Allen and W. A. Lighthall of New York, and Mr. Spencer of England, patented methods of packing the condenser tubes, and the practice of introducing zinc plates in an iron cage suspended in the boiler, to prevent galvanic action, together with methods of intercepting the grease and tallow, and of using much less tallow and oil in the cylinders, has made the surface condenser a reliable apparatus.

Since then Cobb, Volz, and Wheeler of New York, have made improvements in combined surface condenser and feed-water heater, and condenser without any packing, and several types of evaporators have been introduced for the purpose of supplying the deficiency

of fresh water, produced by leaks and waste at the gauge cocks. These evaporate the sea water in a vacuum, which leaves the salt and lime soft and easily removed; so that now, when this surface condensing apparatus is properly attended to, the result is all that can be desired.

The subject of expansion has received careful attention from scientific engineers, by expanding steam



VOLZ'S PATENT COMBINED SURFACE CONDENSER AND FEED WATER HEATER.

of 160 to 200 lbs. pressure in three and four cylinders, with steam jackets made steam tight, with proper means of blowing out the air, and draining off tne condensed water, though the practice of cutting off with the slide valve does not give as good a result as by a separate cut-off valve, as formerly used on the compound and low-pressure engines.

The practice of leaving off, neglecting, and talking against the steam jacket, seems unwise, and shows a

lack of knowledge of the subject. The motive is to save a little expense in the construction, and a little trouble in taking care of it.

J. P. Joule the experimental philosopher has demonstrated, that heat and mechanical force are identical and convertible; that an English thermal unit of heat, or that which is required to raise one pound of water one degree, is capable of raising 772 lbs. weight one foot in height. This is known as the mechanical equivalent of heat, or "Joule's Equivalent." And inversely, 772 lbs. descending, or Joule's equivalent, will raise one pound of water one degree, or produce one thermal unit. Consequently Joule's equivalant is equal to 772 foot lbs., or one thermal unit.

From this it follows that one horse-power, or 33,000 lbs. raised one foot high is equal to $\frac{33000}{772}=42.75$ Joule's equivalents, or thermal units, per horse-power per minute.

Rankine says, "Heat-energy and mechanical energy are mutually convertible, one British thermal unit being the equivalent in heat-energy, of 772 foot-pounds of mechanical energy."

D. K. Clark says, "Heat and mechanical force are identical and convertible. Independently of the medium through which heat may be developed into mechanical action, the same quantity of heat is resolved

into the same quantity of work. The motion gained by the piston of an engine, will be precisely equivalent to the energy, heat, or molecular motion lost by the atoms of the gas; and it would be as reasonable to expect one billiard ball to strike and give motion to another without losing any of its own motion, as to suppose that the piston of a steam engine can be set in motion without a crresponding quantity being lost by some other body."

J. B. Lightfoot of London, in a paper on Refrigerating Machinery, read before the Institution of Mechanical Engineers, 1886, says:

"As mechanical work and heat are mutually convertible, it is obvious that, if during expansion a gas —or steam, for it obeys the same law—is caused to perform work on a piston, its supply of heat must be drawn on to an extent measured by the thermal equivalent of the work done, provided no extraneous source of heat exists from which the deficiency can be made good; and the gas—or steam—after expansion will be colder than it was before expansion. Expansion behind a piston without the addition of heat from any extraneous source is called adiabatic expansion.

From this it will be seen that every horse-power developed in a steam engine, represents 42¾ Joule's equivalents of power or work applied to the machinery, and 42¾ thermal units of heat lost by the steam in the

cylinder. And if steam of 160 lbs. pressure is expanded adiabatically, (or without a steam jacket or superheater) in a triple-expansion engine, with a ratio of 1 to 8 between the high and low-pressure cylinders, and cutting off at half stroke in the high pressure, or 16 expansions, the loss from cylinder condensation must be immense. And in fact it is found to be so, for when such engines are working at half power, it is found to be necessary to open the pass-over valve, so as to admit high-pressure steam to the low-pressure cylinder, in order to prevent the low-pressure piston from pounding on the condensed water in the cylinder.

It would be greatly to the interest of owners to insist that their engines were fitted with properly constructed steam jackets, steam tight, and with provision for freeing them from air and water, and also to insist that the engineers operate them properly, and report results.

D. K. Clark in his manual for Mechanical Engineers, 1889, reports, (from his own experiments on locomotive engines): "That in jacketless cylinders, imperfectly protected, the quantity of steam condensed amounted to from 11 to 42 per cent. of the whole of the steam admitted to the cylinders, according to the period of admission."

He further reports examples on stationary engines

by Mr. Sutcliffe at Saltaire, who found the condensation to be at 7.4 expansions 27 per cent., at 9 expansions 36.6 per cent., and at 11.4 expansions 46.6 per cent.

E. A. Cowper before the Institution of Mechanical Engineers, 1860, showed: "That from indicator figures which he had taken with, and without steam jackets, the loss from the want of the jacket when steam was cut off at 2–7 of the stroke was 11.7 per cent., at 1–5 of the stroke 19.6 per cent., at 1/6 of the stroke 27.2 per cent., and at 1–11 of the stroke 44.5 per cent."

J. Bourne in his "Recent Improvements in the Steam Engine," 1868, published Mr. Cowper's indicator figures or cards, confirming the results from them.

A. M. in "Engineering," April 1874, publishes two sets of indicator diagrams from compound engines built by R. Napier & Sons, which were taken during the voyage, the trial continued 24 hours, the same amount of coal was weighed out each watch, the pressure in the boilers was kept at 58 lbs., but the steam jackets were used only on alternate watches of 4 hours, so that gave three sets of diagrams with, and three without the steam jackets.

The result with steam off the jackets gave 58 revolutions and 1031 H. P. And the result with steam on the jackets gave 63 revolutions and 1182 H. P.; which was a gain of 5 revolutions per min. and 151 H. P., with

the same quantity of coal used in each case. The gain in power was 14.6 per cent. at that degree of expansion when using the steam jackets. From these experiments it does not appear what the heating of the steam jacket cost; but from a paper by Prof. Kennedy of University College London, on compressed air, read before the British Association at Newcastle, 1889, wherein he gives the result of experiments made for several weeks in Paris, with the Popp system of compressed air. The air was compressed at a central station to 75 lbs., then transmitted in pipes 3½ miles, and worked in air engines, (similar to steam engines) to operate machinery.

When the air was used cold it had an efficiency of 46 per cent. of the power applied to compress it. When heated to 392° Fahr., it had an efficiency of 64 per cent., and when water was injected into the heated air it had an efficiency of 87 per cent.

Prof. Kennedy found that when the air was heated it caused a saving of 225 cubic ft. of air per H. P. per hour. This air cost for 10 hours $1.68, and the cost for charcoal to heat the air-heating stove was 12 cents; so that by expending $1.00 for charcoal to heat the air to 392° it produced additional work worth $14.

And as the expansion of all gases and vapors is controlled by the same law, it may be assumed that the cost of heating the steam jackets, will be in the same pro-

portion to the value of the additional work performed.

T. S. Prideaux in his "Economy of Fuel," by J. Weale London, 1853, says on this subject: "Whenever engines are worked expansively, (and all are, or should be) and more particularly condensing engines, heating the cylinder should be deemed an indespensible condition, and to neglect doing so, au act of consummate folly, inasmuch as it is a wanton sacrifice of 30 per cent. of useful effect, when no obstacle exists in the way of its attainment. What makes such remissness the more unpardonable, is the fact, that the advantages of the system have been practically demonstrated and proclaimed in Cornwall for twenty years past; whilst the explanation of its mode of action, was made clear by the publication in 1848, of the researches of Regnault. Extraordinary however as such a statement may seem to the reader, I believe it to be a fact, that there is not at the present moment (1853), either in the Royal Navy or the Mercantile Marine, a single steamer fitted with any apparatus for heating the cylinders, and as a necessary consequence, all their attempts to carry the principle of working expansively, beyond the narrowest limits, prove abortions.

"The cause of this singular supineness must be sought in the fact, that the manufacture of steam engines is regarded too much from a commercial point of

view, by those engaged in it; whilst the want of knowledge of the subject in those who order and pay for them, places them entirely in the hands of the makers."

This was said in 1853, when steam of 20 lbs. was used, and it applies to-day (1893), with much greater force when steam of 180 lbs. is used in common pracice.

One direction in which still greater economy of fuel may be obtained, is by using a still higher pressure of steam. Regnault's experiments show that it costs nearly the same to generate steam at high as at low pressures, as follows: Total heat in degrees Fahr. from water at 32°, at 40 lbs. (including atmophere),

	1162°	At 100 lbs.,	1181°
At 150 lbs.,	1190°	At 200 lbs.,	1197°
At 250 lbs.,	1203°	At 300 lbs.,	1208°
At 350 lbs.,	1212°	At 400 lbs.,	1217°

So that there is only 55° more heat required to generate steam at 385 lbs., than at 25 lbs. pressure above the atmosphere, or about 5 per cent. additional heat; and if steam of 25 lbs. is cut off at $\frac{1}{3}$ of the stroke, its performance is multiplied 2.1 times. On the contrary if steam of 385 lbs. is cut off at 1–30 of the stroke, or expanded 30 times, its performance will be multiplied 4.4 times, or a gain of 210 per cent.

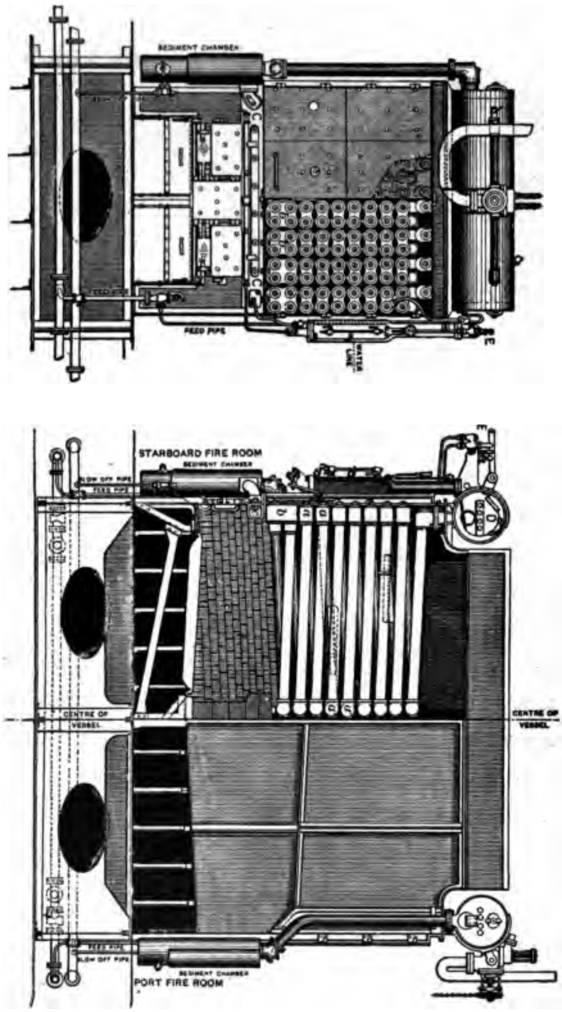
Before such a pressure of steam can be used it will be necessary to have a different type of boiler.

According to U. S. law, in 1860, when steam of 30 lbs. was used, boilers were tested to 45 lbs., leaving a margin of 15 lbs. between the working and the test pressure. Now, in 1893, when steam of 160 lbs. is used, boilers are tested to 240 lbs., leaving a margin of 80 lbs. There does not seem to be any sufficient reason why so great a margin should be required now, more than there was then.

In England under the protest of the builders, who were bursting their boilers while testing them even before they were used, the rule of multiplication was changed to one of addition, and instead of testing to double the working pressure, they now test to 90 lbs. above, leaving a constant margin of 90 lbs. And they gave the reason for adopting that margin, because it happened to be what they were using when they changed the rule.

If a reasonable margin was adopted, say 50 lbs., the working pressure might be increased to 200 lbs., on such a test as is now required for 166 lbs. But before any pressure approaching 400 lbs. can be used, it is most likely that some type of water-tube boiler will have to be adopted. There are now several such boilers before the public.

The Belleville boiler, among the high-pressure water-tube boilers, seems to present very strong claim



BELLEVILLE BOILERS.

for adoption. It was first introduced in France in 1849, and the latest design was made in 1889. It has been extensively used for stationy and marine work, both in the Navy and merchant marine, at pressures up to 200 lbs., and in competition with the Scotch type of boiler. This boiler has been adopted by the Messageries Maritime Co., (one of the largest in France). They have fitted several of their steamers with this type of boiler to the extent of 7,000 H. P.

The French Govt. have fitted one of their vessels with Belleville boilers of 14,000 H. P., one of 8,000 H. P., three of 7,400 H. P., and many others.

The Russian Govt. have fitted one of their ships with boilers of this type of 6,000 H. P., and others of less power. This boiler it is claimed will stand any required pressure, has good circulation, will superheat or dry the steam to a moderate degree, is light and compact, its firebrick furnace is conducive to high temperature, and a more perfect combustion, and economy, it is non-explosive, and easily kept in repair, altogether its adoption seems to be a safe operation, and with it steam pressure and economy can be increased.

The Thorneycroft, Yarrow, Roberts, Almy, an Ward, water-tube boilers are also extensively used, a give satisfaction on small vessels, but thus far have been adopted on large steamships, (1893).

Before the greatest practicable economy of expansion can be reached—in addition to the highest attainable pressure of steam—there should be the smallest possible amount of clearance in the cylinders; the steam should be cut off sharp in each cylinder at the desired point of cut-off; that the speed of piston should be the highest attainable, and each cylinder should be steam jacketed.

According to Boyle and Mariotte's law of the expansion of gases and vapors, the pressure should be one-half, when the volume is doubled, if kept at the same temperature. But in fact the steam expanding in a cylinder adiabatically—or without a steam jacket—is not kept at the same temperature, but is controlled by the law of Dalton and Gay-Lussac, and later experiments of Regnault, that when gases are heated from 32° to 212° they increase in volume 1.367 times, or diminish in the same proportion when the temperature is reduced. So that adiabatic expansion is controlled by the combined laws of Mariotte and Regnault. But when a good steam jacket is used, E. A. Cowper has found that the steam will expand according to the Mariotte law, or when the volume is doubled, the pressure will be one-half.

The author has designed and patented an engine intended to meet these requirements.

The weights of the moving parts, and the pressure due to the work are balanced, by means of compensating cranks, which makes one-half the moving parts balance the other. The working strain or pressure when passing the centres, and consequent friction, is removed from the crank shaft journals—which permits a high speed of piston—and the engines occupy much less space. For small powers they are made tandem quadruple, with one set of cranks. But for large powers they are direct-quadruple, and have two sets of cranks. Several engines built on this plan show great steadiness in working, freedom from vibration, and heating of journals, see the "Neaira's" engines.

Another direction in which still greater economy may be obtained, is by producing a more perfect chemical action in the combustion of coal in the furnace. Chemistry defines combustion as "intense chemical action attended by the evolution of light and heat."

The product of the combustion of coal in atmospheric air, is carbonic acid gas, steam, and nitrogen, which are colorless gases, and whenever smoke appears it is an evidence of imperfect combustion, and consequent waste of fuel.

C. W. Siemens, in a lecture delivered in Bradford 1873, in behalf of the British Association, states: "In burning 1 lb. of carbon in free oxygen, carbonic acid is

produced and 14,500 units of heat or thermal units. But in practice we cannot do that, as we burn coal in atmospheric air, it is safe to assume that not more than 12,824 thermal units can be produced from 1 lb. of coal. Then as one unit produces 772 foot pounds, we have 12,824 x 772=9,900,128 foot pounds from one pound of coal, and if this is divided by 33,000 x 60= 1,980,000 we have $\frac{9,900,128}{1,980,000}=5$ H. P. per hour from 1 lb. of coal, or $\frac{1}{5}=.2$ lb. of coal per H. P. per hour as the theoretical duty of coal.

The lowest recorded duty is by Rankin and Blackmore, which is given at about 1.2 lbs. coal per H. P. per hour, yet this is six times the theoretical duty, which still leaves a large margin for economy.

One cause of this discrepancy or waste is in the high temprature of the waste gases in the chimney, required to produce strong natural draught, particularly to burn anthracite coal. In regard to this, T. S. Prideaux in his "Economy of Fuel," by J. Weale, London, 1853, says:

"I shall no doubt excite general surprise, and perhaps some incredulity, when I state that from a calculation I entered into on the subject (the result of which certainly surprised myself), I find that 1 lb. of coal expended through the mechanical agency of a steam engine, will generate more force, and consequently is

capable of producing a stronger current of air, than 500 lbs. of coal expended in heating a column of air to act by its diminished specific gravity, through a chimney 35 ft. high; and that consequently, all the products of combustion which are allowed to escape out of the furnace into the chimney, before they have fallen below the temperature at which they can be usefully employed—for the sake of producing draught—are most prodigally misapplied.

"Strange to say however, this is the system at present almost universally employed, apparently in utter unconsciousness of its wastefulness, and notwithstanding the fact, that numerous collateral advantages are attendant on the employment of compressed air, not the least of which are the perfect control it gives over the action of the furnace, and the extent to which it enables us to utilize the escaping heat.

"The result of the employment of this wasteful and unscientific system, is seen in the fact, that in steam engines where an intense draught is employed, the consumption of fuel is 25 per cent. more than that of those where the products of combustion are reduced to a comparatively low temperature before they enter the chimney."

These remarks apply with equal force at the present day (1893) to natural draught furnaces.

Another cause of waste is in not introducing air to the furnace in a proper way.

Chas. Wye Williams has treated this subject in an exhaustive manner, and wrote a treatise on the subject, which was published by J. Weale London, 1858, which with extensive additions by D. K. Clark, was republished by Crosby, Lockwood & Co., London, 1886. Mr. Williams demonstrated that in return tubular boilers with a short run back of the bridge, the proper place to introduce air to consume the furnace gases, was at the front of the furnace, through a plate perforated with ½ inch holes, with an area of from 5 to 6 sq. ins., for every sq. ft. of grate, when natural draught was used, this arrangement facilitated the mixture of the air with the combustible gases, while passing over the fire, before they entered the tubes, and were reduced in temperature.

In an experiment by Mr. Houldsworth, made for the British Association at Manchester in 1842, he demonstrated by means of a pyrometer in the furnace, the great increase in the temperature when air was introduced on the plan of C. W. Williams. The decrease when the grate bars became uncovered in places, and when the coal on the grate was leveled—the immediate increase in temperature, which showed the necessity of keeping the grate bars covered.

Without air admission the mean temperature in the furnace was 975°, and the water evaporated per pound of coal was 5.05 lbs. With air admission the mean temperature in the furnace was 1160°, and the water evaporated per pound of coal was 7.7 lbs. Mr. Houldsworth estimated the advantages gained by the admission of air to be about 34 per cent.

The great difficulty with the furnaces in steam ships has been to get the firemen to attend them properly. Mr. Williams states as follows:

"The facility with which the stoker (or fireman) is enabled to counteract the best arrangements, naturally suggests the advantage of mechanical feeders. Here is a direction in which mechanical skill may be usefully employed:—the basis of success, however, should be the sustaining at all times the uniform and sufficient depth of fuel on the bars."

Juke's moving bars, at one time extensively used in England, met these conditions. The bars moved at about 6 ft. an hour, the coal was fed into a hopper at the front, at a uniform thickness, and the clinkers and ashes were delivered at the back, into a truck on a rail-track in the ash pit, on which they were withdrawn.

Owing to the complication of this apparatus, and the difficulty of applying it to marine boilers, it never came into use on them. But in regard to its economy,

and its smoke consuming, or smoke preventing properties, it has never been surpassed. It was a continuous coking arrangement, and the air was admitted with the coal into the furnace. On this subject Mr. Prideaux states:

"If a continuous and equable supply of air is to be furnished to a furnace, then, in order that this supply of air may exactly correspond with its requirements, the supply of fuel must be made continuous and equable also; so that at all times there shall be just the same quantity of fuel in the same state, that is to say, at the same stage of combustion. This appears to be the most perfect method of working a furnace, and the most obvious mode of overcoming the difficulty, and it is accordingly to accomplish this object, that most of the attempts to prevent smoke and attain perfect combustion have been hitherto directed."

This plan as we have before shown, was the one pursued by Watt at Soho, where it was in use 50 years and never produced smoke. The furnace was inclined 25°, and had a broad dead or coking plate, the coal was coked at the front, then pushed back and spread at short intervals.

This method insures a proper chemical action of combustion, the carburetted hydrogen is continuously evolved, the air is continuously admitted to consume it,

and the carbonic oxide which may rise above the fuel on the grate; while the air is applied to the carbon on the grate, from the ash pit.

The author has designed a combined feeding and shaking grate to accomplish these objects. It is a method of operating the ordinary grate bars, and is applicable to any furnace.

Another and a third direction in which greater economy of fuel may be secured, is by the method of heating the air supplied to the furnaces, by the waste heat of the furnace gases.

This method termed the hot-blast system, has long been, and is now almost universally used in the smelting of iron. It was first used by J. B. Neilson, Glasgow, in 1830, where he heated the air to 600° in a separate kiln or furnace, and the consumption of coal was reduced to ⅓ what it had been before. This kiln was afterwards placed over the smelting furnace and the air was heated by the waste gases.

Siemens afterwards introduced his Regenerative hot-blast stoves, in which he used firebrick to absorb the heat from the waste furnace gases, and return it to the blast on its way to the furnace. By this means he obtained a much higher temperature in the blast, than Neilson had done, and a corresponding economy.

F. B. Blanchard of New York, used a hot-blast ar-

rangement on the steamboat, "J. Faron," which ran on the Hudson River in 1857–58, and which showed very good combustion and great economy.

Wm. Gorman of Glasgow patented a hot-blast plan in 1852, made some experiments in 1854, and published results in the London Artizan of 1860.

J. Howden of Glasgow patented a system of hot-blast in 1882, which has been applied to many steamers.

R. Wylie of Hartlepool, England, in 1885 applied a method of hot-blast to the steamer "Stella."

T. Main of New York, in 1886, patented a combination or system of hot-blast, with some of the features of Blanchard's and C. W. Williams' patents, but adapted to present needs.

The object of the latter system is to heat the air which supplies the furnaces, from the heat of the waste furnace gases, by means of an air heater, common to all the boilers, placed at the base of the smoke pipe, and forming a part of it. The air is drawn from over the after boilers, and from the engine room, by a blower operating on cool air before it is expanded by heat, and forced through the air heater to the furnaces, delivering about 80 per cent. below, and 20 per cent. above the grate. The temperature of the waste gases above the air heater is found to be 400 to 450°, and below, 700°; and the temperature of the air entering the furnaces

300°. The saving in coal over the natural draught method is 20 to 25 per cent., according to the firing. When the furnace is kept closed the pressure of steam can be regulated by speeding the blower in the engine room. And when the engines are stopped, the blower can be stopped and combustion arrested completely, and so prevent blowing off steam.

It will be observed that if the air entering the furnace is heated 200 to 250°, it represents that amount less, of heat to be abstracted from the hot coal on the grate, and this is obtained from the waste furnace gases, no combustion can take place until the air is heated to from 800 to 1000°. It is not found to be practicable to heat the air to more than 300°, nor to reduce the waste gases to less than 400 to 450°, for there is a margin needed to transmit the heat from the waste gases to the air, and then if the gases were hotter, that would reduce the heating effect in the boiler.

We have seen that the power to work the blower is so little, that it is scarcely an element in the question, because it renders so much of the heat in the waste gases available for power. It will also be noticed that as the air is so much cooler than the water in the boiler, it will more readily absorb the heat in the waste gases at their low temperatures. The air is admitted high up in the furnace front, which prevents the coal being heated up

at the door, and of course the air being cooler and heavier than the gases in the furnace, will settle down by gravity and mix with them, the air is distributed by a perforated plate in the furnace front after the plan established by C. W. Williams.

It is found that when the air is introduced into the ash-pit, and furnace arbitrarily in the ratio of 4 to 1 so as to supply the needed oxygen to the carbon and hydrogen at the proper time and place, in a heated condition; then the supply of air approximates more closely to the theoretical amount of 150 cubic ft. to each pound of coal consumed, and consequently less surplus air passes through the furnace, and so producing a cooling effect.

This is a thing to be guarded against, particularly when we remember, that for every equivalent of oxygen we receive in the atmospheric air, we are compelled to take four equivalents of nitrogen with it, and this nitrogen is heated in the furnace, and carries off a large mount of heat, which is only partly recovered before it reaches the atmosphere and is lost.

When it is desired to burn a large quantity of coal per sq. ft. of grate, it is only necessary to adapt the capacity of the blower, to the quantity of coal to be burned.

It may further be remarked that this method of artificial draught makes it possible to maintain the steam pressure, without any reference to the condition of the